‘FRONTAL RECESS ANATOMY’

Radiological Study and Its’ Surgical Implications

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF **M.S BRANCH – IV (OTORHINOLARYNGOLOGY)** EXAMINATION OF THE TAMILNADU Dr. M.G.R.MEDICAL UNIVERSITY TO BE HELD IN **APRIL 2014**

CERTIFICATE

This is to certify that the dissertation entitled **'Frontal Recess Anatomy – Radiological Study and Its' Surgical Implications'** is a bonafide original work of **Dr. Saud Ahmed**, submitted in partial fulfilment of the rules and regulations for the **MS Branch IV, Otorhinolaryngology** examination of The Tamil Nadu Dr. M.G.R Medical University to be held in **April 2014**.

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TITLE OF THE ABSTRACT	: Frontal Recess Anatomy – Radiological study and its' Surgical implications
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NAME OF THE CANDIDATE	: Saud Ahmed
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NAME OF THE GUIDE	: Dr. Anand Job

OBJECTIVES

Utilize 3- Dimensional CT scan :

1. To determine the role of various frontal recess cells in the development of frontal sinusitis.
2. To find the variations in the course of the anterior ethmoidal artery, and
3. Review the endoscopic surgical approaches to the frontal recess.

METHODS: Explain the clinical and statistical methods used (maximum 100 words)

It was a retrospective and prospective case control study. Fifty controls and fifty cases were studied.

Controls - Patients who had axial CT scan of temporal bone performed for ear diseases with absence of sinonasal symptoms. 3-D reconstructed images of the frontal recess region were created on a workstation and were reviewed.

Cases - Patients' clinically diagnosed with chronic frontal sinusitis with frontal sinus mucosal thickening > 3 mm on CT scan.

The frontal sinuses (200) were further divided into diseased and non-diseased based on the radiological findings and compared.

The findings were documented and analysed using Stata/IC 10.1 software package. Student ‘T’ test was used to compare the means and Chi-square statistics was used to test the association between the variables. Wilcoxon rank-sum (Mann-Whitney) test was done to see the difference between two groups when the data was not normally distributed.

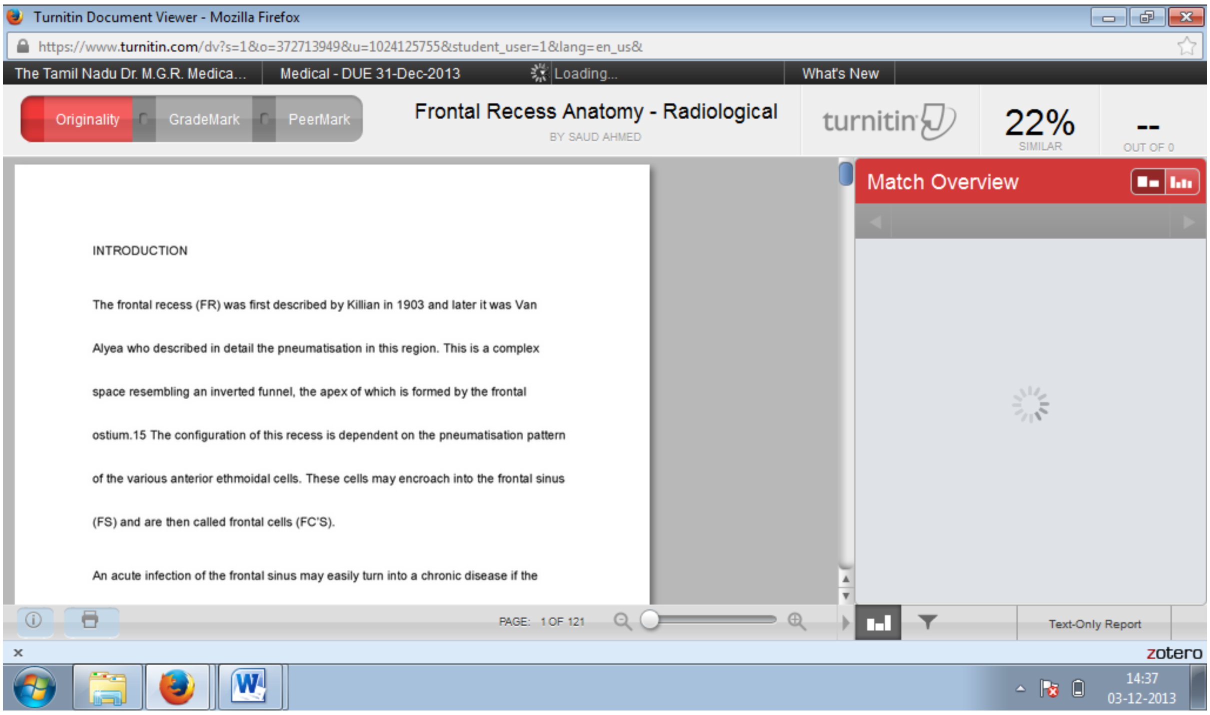
RESULTS

In this study, we could outline the various patterns of pneumatization in the frontal recess in our patients using 3- Dimensional Computerised Tomography.

We did not find a significant relation for any particular frontal recess cell or pneumatisation pattern for being the sole cause for chronic frontal sinusitis. Therefore we conclude that the pneumatisation pattern in combination with various other factors, especially mucosal oedema, contributed to the etiopathogenesis of chronic frontal sinusitis.

The anterior ethmoidal artery was found to run freely in the ethmoids, away from the skull base in most of the patients.

(Key Words : Frontal Recess, Anatomy, Multiplanar Study, Computerised Tomography)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INTRODUCTION
The frontal recess (FR) was first described by Killian in 1903 and later it was Van Alyea who described in detail the pneumatisation in this region. This is a complex space resembling an inverted funnel, the apex of which is formed by the frontal ostium.15 The configuration of this recess is dependent on the pneumatisation pattern of the various anterior ethmoidal cells. These cells may encroach into the frontal sinus (FS) and are then called frontal cells (FC'S).
An acute infection of the frontal sinus may easily turn into a chronic disease if the
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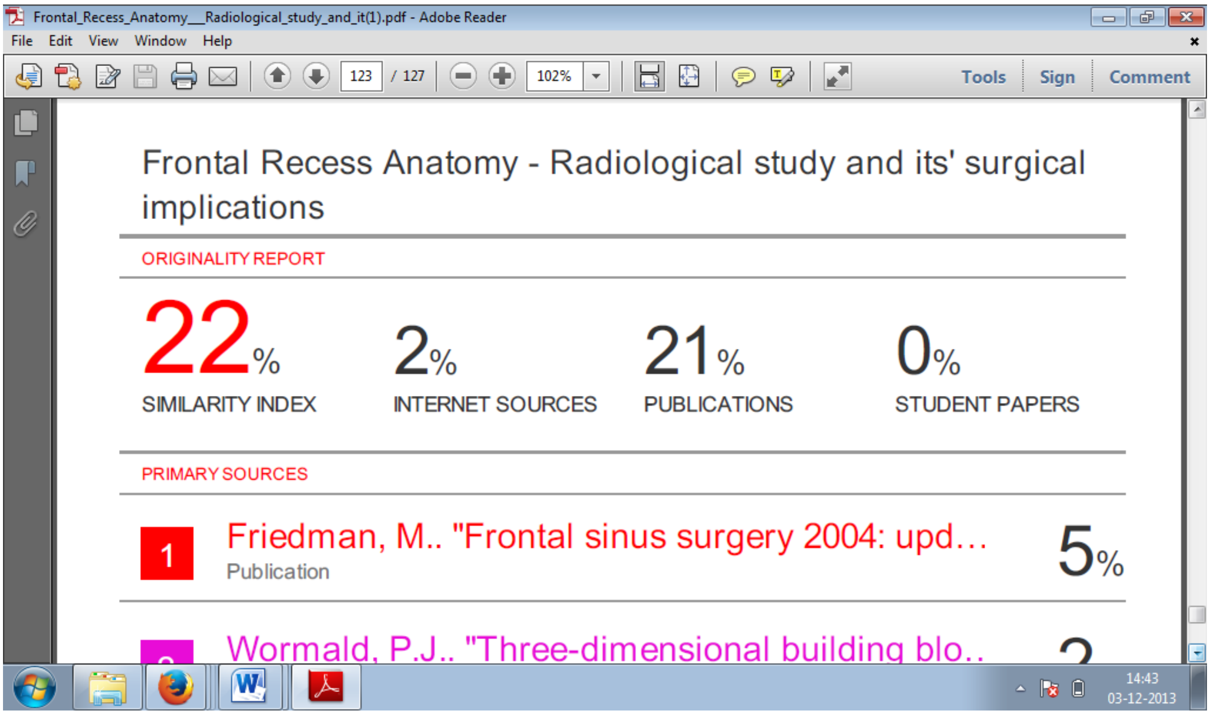

Frontal Recess Anatomy - Radiological study and its' surgical implications

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CONTENTS

		Page No.
1.	INTRODUCTION	1
2.	AIMS & OBJECTIVES	4
3.	REVIEW OF LITERATURE	5
4.	MATERIALS AND METHODS	46
5.	RESULTS	49
6.	DISCUSSION	64
7.	CONCLUSION	75
8.	BIBLIOGRAPHY	76
9.	APPENDIX :	
	PROFORMA	83
	CONSENT FORM	88

INTRODUCTION

The frontal recess (FR) was first described by Killian in 1903 and later it was Van Alyea who described in detail the pneumatisation in this region. This is a complex space resembling an inverted funnel, the apex of which is formed by the frontal ostium.[15] The configuration of this recess is dependent on the pneumatisation pattern of the various anterior ethmoidal cells. These cells may encroach into the frontal sinus (FS) and are then called frontal cells (FC'S).

An acute infection of the frontal sinus may easily turn into a chronic disease if the frontal recess has a curved configuration or in the presence of various types of frontal cells pneumatising along the nasofrontal isthmus. Previous studies [23] have looked at a number of cells which include the agger nasi cell (ANC), supraorbital ethmoidal cell (SOEC), frontal cell (FC), frontal bullar cell (FBC), suprabullar cell (SBC) and interfrontal sinus septal cell (IFSSC) and have found a significant relation of these cells in the pathogenesis of chronic frontal sinusitis.

Computerised Tomography (CT) of the the paranasal sinuses has been traditionally done with coronal 3 mm cuts to obtain a single plane of radiological depiction of sinus anatomy. This is helpful in chronic frontal sinusitis for presurgical mapping and evaluation. However, the erratic and varying anatomy of the frontal recess is difficult to appreciate with conventional single plane axial or coronal CT images of the sinus.The introduction of Three-Dimensional (3-D) CT imaging with added sagittal reconstructions has immensely improved the understanding of this region.

Although a lot of literature about frontal recess anatomy is appearing in the Western literature, there is paucity of Indian studies on this subject.

The anterior ethmoidal artery (AEA) is considered to be an anatomical landmark for recognizing areas of difficult access like the frontal recess. In the field of skull base surgery, the AEA has been instrumental in defining the superior limits of dissection. In depth knowledge of the anatomical course of the artery is very important in preventing trauma to the vessel during endoscopic sinus surgery (ESS). Visualizing the AEA also helps in recognizing and treating cases of uncontrolled epistaxis.

The AEA gains entry into the olfactory fossa through the lateral lamella of the cribiform plate (CP) along the anterior ethmoidal sulcus. In this area, the bone is very thin, and therefore considered to be a risky area in terms of injury during ESS. As the AEA travels through the ethmoids, its' position with respect to the roof is variable making it prone to injury during surgery. It can run in the roof of the ethmoid, or appear prominent in a mesentery, or lie freely in the anterior ethmoidal cells. Obtaining a High-Resolution CT scan is helpful in accurately locating the vessel. [25]

Compared to the other sinuses, operating the frontal sinus endoscopically, poses a major challenge to the surgeon owing to the presence of various anatomical constraints. Therefore, exposing the FR and FS keeping in view its variable range of air cells like the ANC to the IFSSC and FC's, requires adequate experience, skill and a well defined plan along with suitable instrumentation to achieve complete clearance of disease from this region.

Whether the approach to the FR is utilizing the agger nasi cell as landmark as in axillary flap approach or the uncinate process attachment or the intact bulla technique, or the

Wigand technique, the selection of the approach has to be prioritized based on a three dimensional radiological study of the frontal recess so that each cell in the region can be removed allowing adequate frontal sinus drainage and at the same time without injuring the surrounding vital structures.

AIMS

1. To utilize 3- Dimensional Multiplanar Reconstructed Computed Tomography for assessment of the pneumatization pattern of the frontal recess in normal population and in patients with chronic frontal sinusitis.

2. To utilize the same and characterize the variations in the course of the anterior ethmoidal artery canal within the ethmoid sinus.

3. Review and analyze some of the popularized endoscopic surgical approaches to the frontal recess.

OBJECTIVES

1. To determine the role of various frontal recess cells in the development of frontal sinusitis.

2. To find the variations in the course of the anterior ethmoidal artery (AEA) in our population.

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REVIEW OF LITERATURE

The Frontal Sinus (FS)

Volcher Coiter, a pupil of Fallopius and Eustachius, is said to be the first to describe the frontal sinus. This sinus along with the maxillary and ethmoidal sinuses arises by invagination of the nasal mucosa at certain points in the lateral nasal wall. This gives rise to nasal pits which go on to develop into the anlages of the sinuses.[1] The frontal sinus is an air filled cavity which is pyramidal shaped and lies inside the frontal bone sandwiched between an anterior and posterior table. The anterior table is thicker compared to the posterior table which separates the sinus from the frontal lobe of the brain.

The medial wall of the FS is formed by a bony septum called the intersinus septum, which at times can be pneumatised and form an intersinus septal cell and its' floor corresponds to the anterior roof of the orbit. At the inferior aspect in the midsagittal plane the outer table of the frontal sinus is about twice as thick as the posterior inner table. The extent of the anterior wall of the FS is from the nasofrontal suture line above to just below the frontal bone protuberance inferiorly, along the vertical part of the frontal bone.

The anterior wall is layered by a thick external periosteal layer called pericranium and this is followed superficially by the frontalis muscle then the subcutaneous fat followed by the skin.

Its' posterior wall constitutes a large portion of the antero-inferior boundary of the anterior cranial fossa. This also lies in close contact in relation to the frontal lobes and is separated only by the duramater. It can be divided into a superior, vertical, and a small inferior portion which is horizontal and forms portion of the orbital roof. The posterior walls combine inferiorly and form a structure called the internal frontal crest. This structure gives insertion to the falx cerebri.

The intersinus septum is a triangular shaped partition which separates the FS’s into two independent draining compartments. This septum is considered to be the anterior elongation of the embryological suture line. Eventhough the septum varies in direction and also in thickness as it extends superiorly, the lower part of the septum is always near to the midline around the level of the infundibulum. Here, the septum in its’ posterior part is continuous with the crista galli. Inferiorly it is continuous with the perpendicular plate of the ethmoid and anteriorly it is continuous with the the nasal spine of the frontal bone.

As mentioned earlier, the falx cerebri gets inserted into the posterior table of the FS and this point corresponds to the posterior edge of the septum. Additionally, intersinus septum may be pneumatised with cells and often the pneumatisation from these cells might extend into the crista galli. The IFSCC’s drain into the nasal cavity through their own separate outflow tract which is just beside the normal FSOT, at the level of infundibulum either on one or both sides of the nose.

The FS when traced inferiorly is limited by the supraorbital rim. This rim gives access via the supraorbital foramen to the supraorbital neurovascular pedicle. This neurovascular tissue travels towards the skin of the forehead. At the supraorbital rim, the FS is funnel shaped and forms the base of a pyramid. Barring the thin septations seen in the ethmoidal cells, the inferior wall of the FS forms one of the weakest walls of all the sinuses.

Laterally the FS cavity is seen to extend as far as the angular prominence. The superior border of the FS is not pneumatised and is the cancellous part of the frontal bone.

Yun et al [2], in their study on frontal sinus dimensions reported that in adults, the mean height, width, depth and volume of the frontal sinus were 27.2 ± 7.0 mm, 52.5 ± 17.1 mm, 22.0 ± 6.3 mm, 8.39 ± 3.78 cm^3, respectively.

The frontal sinus drainage pathway is made up of three different regions and is shaped like a hourglass. The upper portion of the hourglass is marked by the frontal sinus itself. The mid portion is the narrowest portion and corresponds to its' ostium while the lower portion is formed by the frontal recess.

The Frontal Ostium

The frontal ostium is bounded by the roof of the ANC antero-inferiorly, the roof of the bulla ethmoidalis or suprabullar cells (SBC's) posteriorly, the lamina papyracea (LP) laterally and the lamella of the middle turbinate (MT) anteriorly.

Landsberg et al [4] in their study reported the dimensions of the frontal ostium as follows: (Fig.01 & Fig.02)

Anterior–posterior diameter : 7.22 mm with a standard deviation (SD) of 2.78 mm
Transverse diameter : 8.92 mm with a SD 2.95 mm

Mean sectional area of the frontal ostium was calculated by using the following equation :

Elliptical area = R1 [radius (anterio-posterior)] x R2 [radius (transverse)]

They found that the **mean sectional frontal ostium area** equalled 50.5 mm^2.

The Frontal Recess

This recess (Fig.03) was first described by Killian in 1903 and later it was Van Alyea who extensively described the pneumatisation patterns in this region.The frontal recess is also called as nasal part of frontal sinus, frontal infundibulum or nasofrontal duct. This space determines the frontal sinus drainage pathway because of which the frontal sinus status is largely dependent on the frontal recess conditions.

The boundaries of the frontal recess are as follows: (Fig.04)

Medial : middle turbinate

Lateral : lamina papyracea, lacrimal bone

Superior : skull base

Inferior : dependent upon the attachment of uncinate process

Anterior : agger nasi cells

Posterior : anterior ethmoid artery / bulla ethmoidalis

From development point of view, this space is the superior contribution of the ascending branch of the first primary interturbinal furrow which is the groove between the first & second ethmoturbinal crests. The frontal sinus originates from pneumatization of the frontal recess in an antero-superior direction, into the frontal bone.

Anywhere between one to four frontal pits grow cephalad from the middle meatus to form the anterior ethmoid cells and pneumatise each half of the frontal bone. Usually the second frontal pit becomes the frontal sinus. Other frontal pits that do not become the frontal sinus may develop into agger nasi cells, frontal cells, supraorbital cells or intersinus septal cells. These cells can become primarily infected or even obstruct the frontal sinus drainage. [14]

Compared to the other sinuses, the frontal sinus is the last paranasal sinus which starts developing and also the last to complete its' development.

Early in 1916, Schaefer was able to describe several (1-4) pits or frontal furrows which ultimately end up in forming the frontal sinus and various anterior ethmoidal cells. [59]

The delineation of these furrows was described by Kasper [60] as follows

1st furrow – Agger nasi cell

2nd furrow – Frontal sinus

3rd & 4th furrow - Anterior ethmoid cells

This was based on dissection of specimens.

He further suggested that the frontal sinus originates from :

Frontal anterior ethmoid cells & frontal furrows – 57%

Infundibular anterior ethmoid cells – 34%

Extension of the ethmoid infundibulum – 4%

According to Stamberger, the frontal recess develops at the superior aspect of the groove between the 1st and 2nd ethmoturbinals.

The frontal sinus cannot be visible at birth in most individuals. This is based on CT scans which demonstrated the sinus in only 12%, and in these cases also it was minimally developed. [61]

At around the age of four years,

Length – 4 - 8 mm

Height – 6 – 9 mm

Width – 11 – 9 mm

At around twelve years, a tetrahedral shape is formed and this will continue to aerate till early adulthood.

One thing worthy of mention is that similar to the sphenoid sinus, the FS develops mostly in the postnasal period. As a result, the FS is also prone to similar developmental issues like hypoplasia seen in patient suffering from cystic fibrosis.

Various Cells in Relation to The Frontal Recess

Agger nasi cell (ANC)

It is the most constant and anterior of the ethmoid cells (Fig.05) related to the frontal process of maxilla anteriorly, frontal sinus and frontal recess superiorly, nasal bones antero-laterally, lacrimal bone infero-laterally, uncinate process infero-medially, and by ethmoid infundibulum posteriorly. The size of the frontal beak will vary depending on the degree of pneumatisation of the agger nasi cell.

In case there is a large cell, then the beak will be small. If this cell is absent or under-pneumatized, then the frontal beak will extend significantly into the frontal recess making the frontal ostium smaller in size.

Fernando et al [3] reported the incidence of ANC's as 98.7% .

<u>Frontal cell (FC)</u>

A Frontal cell occurs superior to an ANC, and is similar to an ANC because its' superior and posterior wall are seen as partitions inside the FR or within the FS depending on the type of cell. (Fig.05)

Bent et al [5] proposed a definition to distinguish among the various frontal recess cells.

Type 1 (FC1) – single frontal recess cell above agger nasi and is located below the frontal beak (Fig.06)

Type 2 (FC2) - tier of cells in frontal recess above agger nasi cell and all are located below the frontal beak (Fig.07)

Type 3 (FC3) - single cell above the agger nasi ,which extends from the frontal recess into the frontal sinus (Fig.08)

Type 4 (FC4) - isolated cell in the frontal sinus (Fig.10)

Langille et al [6] based on 328 CT scans reported the proportion of frontal cells as follows:

Type 1 - 26%

Type 2 – 6.4%

Type 3 – 2.1%

Type 4 – 0% .

Supraorbital ethmoidal cell (SOEC) (Fig.11)

This is an ethmoidal cell from the frontal recess that extends over the orbit and is located posterior to the AEA and maybe either single or multiple. This cell drains into the lateral aspect of the FR.

Leunig et al [8] reported an incidence of 10.2% and Zhaang et al [7] reported an incidence of 5.4% in their study in a Chinese population.

Suprabullar cell (SBC)

This is an ethmoid cell above the ethmoid bulla, superior wall of which is anterior cranial fossa skull base. Its' anterior border does not extend into frontal sinus. This cell may represent pneumatization of the anterior wall of the ethmoid bulla and closely resembles the suprabullar recess.

Leunig et al [8] in their study reported the incidence of suprabullar cells as 28.2%.

Frontal bullar cell (FBC)

This is an ethmoid cell placed superiorly above the ethmoidal bulla, and this is seen to pneumatize along the skull base and extends into the FS. The skull base forms the roof of these cells and are seen well on sagittal scans close to the skull base as they migrate into the frontal sinus. These cells can push the drainage pathway of the frontal sinus anteriorly and compromise the drainage. (Fig.08)

Leunig et al [8] reported the incidence of frontal bullae as 16.0% in their study group.

<u>Interfrontal sinus septal cell (IFSSC)</u> (Fig.09)

This cell is commonly seen associated with the FS septum and usually derived from the FS itself. The IFSSC pneumatises from the frontal recess through the frontal ostium and its medial wall is the intersinus septum of the FS.

These cells vary in size and tend to push the frontal sinus drainage pathway laterally. A large cell can also compromise the drainage of the frontal sinus.

The surgical anatomy of the various cells in the frontal recess can be divided into three groups on the basis of their anatomical locations in the FR. The anterior group comprises of cells like the ANC and FC. The posterior limit of these cells is marked by a free partition in the FR. The anterior limit of cells like ANC, FC1, FC2, and FC3 is marked by the anterior wall of the FR and the surrounding anterior wall of the FS. However, the anterior wall of the FC4 is marked by the anterior wall of the FS.

The posterior group of cells includes the FBC, SBC, and SOEC. In these three cell types, the base of the skull marks the superior or posterior limit of the cell.

Eventually, the medial FR is the entrance for the IFSSC as well as the FS, the ostium of which is found in the medial frontal recess.

Suprabullar Recess

This forms a discrete potential space between the bulla and the skull base. The anterior ethmoid artery is very often seen to be located in the superior portion of the suprabullar recess.

Other Air cells

Haller cell

This is an air cell that extends into the roof of the maxillary sinus beyond the limits of the ethmoid capsule and is also called as infraorbital cell.

Onodi cell

This is a posterior ethmoid cell that extends posteriorly into the sphenoid bone lying laterally and superior to the sphenoid sinus to abut the optic nerve.

Utility of Sagittal Reformatted Computerized Tomographic Images in the Evaluation of the Frontal Recess

CT scans are used as an aid in both the diagnosis of chronic sinusitis and for the pre-operative planning during endoscopic sinus surgery. However, studies have shown that there is a significant incidence of mucosal abnormalities seen in completely asymptomatic patients.[36] The timing of the scan is very critical when imaging patients with chronic sinusitis.[56] Therefore it is important for the patient to undergo adequate medical treatment for the nasal and sinus condition before a CT scan of the sinuses is performed. [37]

The primary scan used to assess the anatomy of the sinuses is the coronal scan. [38] These scans should be close together by which an identified cell can be followed from one cut to the next. With this, a three- dimensional image of the anatomy can be reconstructed from the scans. [39-41] The sagittal scan gives significant information about the anterior and posterior group of cells and differentiates between a frontal bullar cell and a type 4 frontal cell .The axial scan is important in determining the drainage pathway of the frontal sinus.

Computerized tomography of the paranasal sinuses classically has been performed with coronal 3 mm slices to provide single plane of morphologic depiction of sinus anatomy for preoperative mapping and evaluation. The complex and erratic anatomy of this region is difficult to appreciate with conventional axial or coronal CT images. Recent advances in computer tomography provide multiplanar 1mm reconstructed images (axial, coronal and sagittal) of frontal sinuses and their corresponding drainage pathway.

Current CT scan imaging protocols for paranasal sinuses utilize multislice CT helical scanner which perform scans in the axial plane at 0.5 to 1 mm intervals along with coronal and parasagittal reconstruction.[35] The windows of the scan are set at between 1500 and 2000 with a centre of +100 to +300 for high bony definition. In case there is a suspicion of fungal sinus disease, the window settings are set to soft tissue settings.

Kanowitz et al [9] reported that sagittal reformatted CT images of the PNS were helpful in the radiologic evaluation of the Frontal Sinus Outflow Tract (FSOT) and experienced neuroradiologists had a higher degree of confidence in the diagnosis of the obstruction of the FSOT using sagittal reformatted images.

Sagittal reconstructions help in providing a more complete depiction of the patient's anatomy, when compared with a conventional 3-mm coronal CT, which continues to be the mainstay of most CT scans of the paranasal sinuses.

Kew et al [10] in their study have already stressed the superiority of sagittal images for the description of the frontal recess anatomy. They also reported that a preoperative review including both sagittal and coronal images significantly changed the surgical planning in more than one-half of cases when compared with review of coronal cuts alone.

Lee et al [11] in their study have concluded that the sagittal CT scans were extremely helpful in the evaluation of ANC, FC, SBC, and FBC.

Physiology of The Frontal Sinus

The frontal sinus is the only paranasal sinus in which there is an active inwardly directed transportation of mucus. Along the interfrontal septum, mucus is transported into the frontal sinus, then laterally along its' roof and back medially via the floor and inferior portions of the posterior and anterior wall of the sinus. The secretion then exits the frontal sinus via the lateral aspect of its' ostium. It is seen that not all of this mucus leaves the sinus after one 'round trip'. This is the result of a whorl-like formation in the ciliary pattern, which may be present in a shallow sulcus immediately above the frontal ostium as well as inferior to it in the frontal recess.

An unspecified quantity of mucus comes into contact with the inwardly directed transport route again and thus may recycle through the sinus several times.[12] Once it has passed out of the ostium the secretion is then transported through a narrow cleft of variable dimensions, which is nothing but the frontal recess which ultimately drains either directly into the ethmoidal infundibulum from above, or medial to the infundibulum in cases where the infundibulum ends in a blind pouch.

The frontal recess depending on the existing anatomic variations collects the secretions from the ethmoidal compartments and eventually the secretions from the frontal sinus merge with the secretions from the maxillary sinus and together they are transported back towards the nasopharynx. [12]

The mucosa of the FS has close resemblance to the upper respiratory mucosa with its columnar epithelium. There are also numerous goblet cells and glands which produce mucinous and serous secretions. The mucosa of the FS constantly produces secretions which help to ensure that the cavity is every time cleared of particulate matter. This also helps in adequate humidification.

Eventhough finally the secretions reach the frontal recess, the secretions recirculate many times through the entire FS cavity, along the intersinus septae before finally passing out into the nose through the FR. The frontal recess connects internally with the interior and medial region of the frontal sinus. This internal frontal ostium is not always the most inferior or gravitationally dependant region of the frontal sinus.

However, the frontal sinus mucous membrane cilia transport the mucus blanket over the grooves and crevices of the sinus until it reaches the ostium. In 1932, Hilding demonstrated that the mucus blanket travels in a spiral towards the internal ostium by effectively defying gravity. Messelklinger confirmed Hilding’s work 35 years later and made the additional discovery that a portion of the mucous blanket actually recirculates within the frontal sinus and frontal recess while the remaining mucus enters the middle meatus.

The frontal sinus has several hypothetic functions. It acts as a buffer for the brain in forehead trauma, contributes to the contour of the forehead, reduces the weight of the cranium, and adds resonance to the voice. Mucociliary clearance mechanics help keep the sinus aerated and prevent airborne particulate contamination and fluid collection.[14]

Pathophysiology of Frontal Sinusitis

Frontal sinusitis is either directly related to impaired mucociliary clearance or anatomic obstruction. Because the frontal sinus drains into the middle meatus through the anterior ethmoid sinus, the patency and lack of disease in this region is important for normal frontal sinus function. Various causes of frontal recess obstruction include air cells, soft tissue, postsurgical scarring, frontal and nasoethmoid trauma. This study is aimed at looking at the air cells in their role in predisposing to chronic frontal sinusitis.

The ANC may obstruct the inferior aspect of the frontal recess where it enters the middle meatus and interfere with effective drainage of secretions. The frontal cell lies superior to the ANC and may impinge upon either the nasofrontal isthmus or frontal sinus. As the supraorbital cell aerates the orbital plate of the frontal bone, lateral and posterior to the frontal sinus, this cell tends to push the frontal sinus drainage pathway anteriorly and medially. This cell may either primarily opacify or obstruct the frontal sinus, leading to a secondary frontal sinus infection.

Large cells within the frontal sinus septum may block the internal ostium of the frontal recess. Other causes of obstruction of frontal recess are chronic inflammatory tissue, allergic fungal sinusitis, polyp formation, frontal sinus trauma, and iatrogenic factors.[14] If the patency of the FSOT cannot be maintained, as a result of oedema, fibrosis, neoplasm or polyps this will cause a vicious cycle of events with the end result of accumulation of secretions. These secretions can have secondary bacterial colonization which gives rise to hypoxia, pH changes, and ciliary motility dysfunction. Either one or all of these changes may cause chronic rhinosinusitis.[13]

Kuhn listed a number of cells which can predispose to obstruction of the frontal recess and thus cause chronic frontal sinus disease. These are namely the FC's, ANC's, SOEC's, FBC's, SBC's and IFSSC's. [15]

According to John P. Bent et al [49] in an article "The Frontal Cell As a Cause of Frontal Sinus Obstruction" the frontal cell is a rare anatomic anomaly that can become the etiology of chronic frontal sinusitis.

Sedaghat et al [18] , in their study found a positive relation between the presence of frontal intersinus cells (OR = 18.37) with development of chronic rhinosinusitis on both univariate and multivariate logistical regressions.

Lien et al [23] in their study concluded that frontal and ethmoidal cells posterior and postero-lateral to the FR (SBC's, FBC's, and SOEC's) have a higher statistical association with the development of frontal sinusitis when compared to the cells anterior to the FR (ANC's, FC's type 1,2 and 3).

Moreover, the presence of SOEC's as confirmed by CT images indicate the highest odds of frontal sinusitis which was followed by SBC's, FBC's, and Recessus Terminalis.

However, in contrast, Del Gaudio et al [19] in their study reported that the FC's and ANC's were not significantly associated with a greater incidence of frontal sinusitis. They also reported that there was no significant association between the area of the nasofrontal isthmus and the occurence of chronic frontal sinusitis.

They concluded that even though anatomical variations in the frontal recess are likely to play a role in predisposing to frontal sinusitis, the mucosal inflammatory processes have a larger and more important role as a causative factor.

Jacobs et al, also reported that in addition to anatomical causes, mucosal edema causing obstruction of the FR has a pivotal role in the pathogenesis of chronic sinusitis.[1]

An anterior rhinoscopy forms the baseline clinical examination of the nose and indications for nasal endoscopy include : [62]

1. Symptoms of the sinonasal tract that are refractory to appropriate empirical therapy or in cases where there is suspicion of chronic rhinosinusitis.

2. In cases where there is a unilateral disease wihout DNS to any side.

3. Symptoms which are disabling and often severe and these are attributed to the nose or sinuses.

4. When there is suspicion of an impending complication of sinusitis.

5. Immunocompromised states like leukemias, diabetes etc.,

6. Post surgery assessment of disease status.

Uncinate Attachment and its' Relation to The Frontal Sinus Outflow Tract (FSOT)

The uncinate process (UP) is a sickle shaped bone extending from the frontal recess superiorly and inferiorly attaching to the inferior turbinate. The superior insertion of the UP is a vital landmark in the region of the FR.

Landsberg and Friedman [4] described two kinds of FSOT that were lying either medial or lateral to the UP. They also classified the superior attachment of the UP into six types as follows: (Fig.12)

Type 1 : insertion into lamina papyracea (LP)

Type 2 : insertion into posteromedial wall of ANC

Type 3 : insertion into both LP and the junction of MT with cribriform plate

Type 4 : insertion into junction of MT with Cribriform Plate (CP)

Type 5 : insertion into skull base (SB)

Type 6 : insertion into MT

They found that in 173 (60%) of the 288 sides they could identify the uncinate process' superior attachment but could not identify the attachment in 115 (40%) sides. In 52 sides (18%) it was because of a mucosal disease making the fine bony septa indistinct. In 43 sides (15%) it was because of previous endoscopic sinus surgery that disrupted the natural anatomy, and in 20 sides (7%) it was because of an inability to clearly define the final destination of the superior attachment. A total of six pattern types were noted in the superior attachment of the uncinate process :

- To the LP in 52%,
- To the posteromedial wall of the ANC in 18.5%,
- To both the LP and the junction of the MT with the CP in 17.5%,
- To the junction of the middle turbinate with the cribriform plate in 7%,
- Ethmoid roof in 3.6%, and
- To the MT in 1.4%

Turgur et al [17] evaluated the relation between frontal sinusitis and the placement of the frontal sinus outflow tract either medial or lateral (Fig.13) to the superior insertion of UP in 243 patients (486 sides) using CT scans. They identified the superior attachment in 361 of 486 sides (74%) and could not identify attachment in 125 sides (26%). Medial drainage was found in 66% and lateral drainage was found in 35%. Insertion of Uncinate Process into LP was the most common type (63%). Insertion into Skull Base was 2nd most common (14%).

<u>Prevalence of superior attachment :</u>

Type 1,2 : 63%

Type 3 : 3%

Type 4 : 12%

Type 5 : 14%

Type 6 : 8%

They also reported that cases with medial drainage were linked to the presence of frontal sinusitis and this was statistically significant ($p<0.001$)

Radiological grading system for sinusitis [13]

Task force on rhinosinusitis recommended staging systems for outcomes Research. This staging combined quantification along with ease of application. Different staging systems have been described. Lund Mackay system has the highest level of inter and intraobserver agreement.

Lund Mackay System

Sinus	Right	Left
Maxillary		
Anterior ethmoid		
Posterior ethmoid		
Maxillary		
Sphenoid		
Frontal		
Osteomeatal complex		

For all sinuses except osteomeatal complex :

0- No abnormality

1- Partial opacification,

2- Total opacification

For osteomeatal complex

0– Not occluded,

1- Occluded

Levine and May

Stage	Disease Status
0	Normal
1	Disease limited to osteomeatal complex
2	Incomplete opacification of one or more sinuses (frontal, maxillary, sphenoid)
3	Complete opacification of one or more major sinuses, but not all sinuses
4	Total opacification of all sinuses

Friedman System

Stage	Disease Status
0	Normal
1	Single focus disease (involving a single focus or single sinus unit)
2	Multifocal disease (bilateral or multiple areas of disease that are not confluent or diffuse throughout the ethmoid labyrinth/bilateral middle meatal polyps)
3	Diffuse disease (extensive bilateral involvement of multiple sinuses) without bony changes
4	Diffuse disease with bony changes

Kennedy System

Stage	Disease status
0	Normal
1	Anatomic abnormalities, all unilateral sinus disease, bilateral disease limited to ethmoidal sinuses
2	Bilateral ethmoidal disease with involvement one dependent sinus
3	Bilateral ethmoidal disease with two or more dependent sinuses on each side
4	Diffuse sinonasal polyposis

Giklich and Metson (Harvard System)

Stage	Disease
0	Normal (<3mm mucosal thickening on any sinus wall)
1	All unilateral disease or anatomic abnormality
2	Bilateral disease limited to ethmoidal or maxillary sinuses
3	Bilateral disease with involvement of atleast one sphenoid or frontal sinus
4	Pansinusitis

Anterior Ethmoidal Artery (AEA)

The AEA arises from the ophthalmic artery and can be considered to be a major anatomical landmark in endoscopic sinus surgery (ESS). This artery passes in the anterior ethmoid canal and is seen either along the ethmoidal roof or under it. The nasal branch passes to the superior most walls and roof of the nasal cavities. The localisation of its position is crucial to the surgeon in order to avoid injuring the artery during ESS and also helpful while performing endoscopic cautery of the AEA in epistaxis not controlled by conservative treatment. It is also an aid to locate the thinnest portion of the ethmoidal roof. [24]

During its course the AEA crosses the orbit, ethmoidal labyrinth and anterior cranial fossa. The AEA enters the olfactory fossa through the lateral lamella of the cribriform plate along the anterior ethmoidal sulcus. The bone over the anterior ethmoidal sulus is quite thin and is at risk of injury during endoscopic surgery. The relationship of the AEA to the roof of the ethmoid is highly variable and is at risk during endoscopic sinus surgeries. Identification of this artery is also important in identifying frontal sinus outflow tract and superior limits of skull base. (Fig.14 & Fig.15)

The AEA can run in the roof of the ethmoid, or appear prominent in a mesentery, or lie freely lower down in the anterior ethmoidal cells. Obtaining a high-resolution CT scan is helpful in precisely locating the artery.

The AEA with its' corresponding nerve run across the fovea ethmoidalis at a 45 degree angle from lateral to medial. In majority of the cases it is found behind the upward continuation of the bulla ethmoidalis. In cases of a suprabullar recess, the AEA can be located in the roof of the suprabullar recess.

If the AEA is cut during surgery (usually when it is in a mesentery) it may retract into the orbit and cause bleeding within the orbital tissues which can create an increase in the intraorbital volume and result in proptosis.

Subsequently the increased pressure may stretch the fibers of the optic nerve and also cause decreased arterial blood flow to the retina resulting in blindness.

Areas supplied by Anterior Ethmoidal Artery

With regards to the paranasal sinuses, the AEA supplies the anterior ethmoidal cells along with the FS. As it travels along the olfactory recess it gives rise to meningeal branches. The AEA also supplies the anterior 1/3rdof the nasal septum along with the lateral nasal wall.

Stamberger reported that the AEA may be in close contact with respect to the skull base, particularly when the roof of the ethmoid sinus is low.

However, he reported that in majority of the cases a bony mesentry connects the AEA to the skull base making it prominent. He further reported in some cases there could be a space of about 5 millimetre between the AEA and skull base.

According to Gotwal who elaborately studied the course of the AEA by viewing coronal CT images of paranasal sinuses, the presence of a bony notch along the medial wall of the orbit points to the probable site of the anterior ethmoidal foramen. He also suggested that the presence of focal narrowing in the olfactory fossa could precisely identify the position of AEA.

Lannoy et al [25] showed that there is a very significant relation between CT images and endonasal dissections in locating the AEA.

Based on the anterior ethmoidal roof, the artery can be divided into 3 grades. [25] (Fig.16)

Grade I - artery running in the roof

Grade II - artery running under the roof and considered as prominent

Grade III - artery distant from the ethmoidal roof

Basak et al [26] in their series found 43% of the AEA to be away from the ethmoidal roof.

Floreani [43] et al reported that the AEA may lie in a mesentery suspended from the skull base with an incidence of 34%.

In cases where the AEA is prominent or dehiscent, the artery is more frequently injured since it is not protected by the anterior ethmoidal roof. This roof also serves as a vital landmark and an outer limit for endonasal dissection during ESS. However, the AEA is more easily approachable and easily cauterized when lying freely (grade 3) in the ethmoidal cavity.

According to Soraia et al [27], the following anatomical landmarks used for identifying the AEA were reliable . The medial wall of the orbit has a bony notch and this corresponds to the anterior ethmoidal foramen. A bony sulcus on the lateral wall of the olfactory recess corresponds to the anterior ethmoidal sulcus.

According to Anagha et al [28] a simple and reliable method for identifying the AEA is by using the orbital beak and the superior oblique muscle as anatomical landmarks. They also concluded that there exists a strong correlation between the vertical distance of the artery from the base skull and the presence of the SOEC.

AEA is classically located between the second and third lamella, which means to say that it will be present on the skull base between the attachments of the bullae ethmoidalis and middle turbinate to the skull base. This area also represents the region where the skull base starts to slope upwards as one traces the skull base from the posterior ethmoids into anterior ethmoids.[58] (Fig.17)

Endoscopic Approaches to The Frontal Sinus

Functional endoscopic sinus was introduced over two decades ago and since then has been instrumental in revolutionizing the surgical management of chronic sinusitis.

Widespread use of CT scans and introduction of various endoscopes has led to a better understanding of the anatomy of paranasal sinuses.

ESS is well established as the technique of choice in treating chronic rhinosinusitis refractory to medical therapy. However, the FR and FS remain a big challenge.[45-47] The anatomy of this region is highly variable and moreover surrounded by the potential danger of injuring the thin partition of the lateral lamella of the olfactory fossa medially and the LP laterally.

Posteriorly, the FR is bounded by the superior continuation of the bulla ethmoidalis (BE) and the AEA. In cases where the anterior face of the BE doesn’t reach the skull base, a supra bullar recess results (SBR). The SBR brings the AEA into the FR. [48]

Previously, there has always been a hesitance to routinely clear a diseased FR because of the fear of this resection resulting in subsequent scarring and blockage of the frontal ostium.[35] But it should be known that scarring is more likely to happen if the raw edges or mucosal surfaces of partially resected cells which are closely approximated continue to remain in the FR. In such scenarios, scar tissue resulting between such raw surfaces might turn up with blockage of the frontal sinus ostium and subsequent worsening of the already present chronic frontal sinus disease.

This property of the FR to scar and end up in obstruction has led to an all or nothing approach for exploring the region, with either each and every diseased cell being cleared from the FR or for no surgery to be undertaken. If the FR and or the FS remains refractory to suitable medical therapy ,then the surgeon has to plan exploration of the FR and adequate exposure of the frontal sinus ostium.

Before embarking on such a plan, the surgeon should to have a general understanding of the commonly encountered variations that are known to occur in the FR.[49] Review of literature shows that the surgical management of chronic frontal sinusitis continues to undergo change with no universally accepted procedure. The different procedures can be broken into two main groups, the first involving obliteration or ablation of the sinus with blockage of the frontal sinus drainage pathways. Procedures in this category include the Reidel (1889) & Killian operation [29] described in 1903, frontal sinus cranialization, and the osteoplastic frontal sinus procedures.[30]

The second group involves reestablishment of the outflow tract and re-aeration of the sinuses. These frontal sinus preservation procedures include the external frontoethmoidectomy by Lynch [31] in 1921, the endoscopic intranasal frontalsinusotomy,[32] the above and below procedure [34], and the recently popularized modified endoscopic Lothrop procedures. [33] Here we plan to review some of the popularized frontal sinusotomy approaches.

Nasal Endoscopes

Rigid endoscopes give a very good image clarity, expecially when used with digital video chip. This has greatly helped in surgical instrumentation of the nose and sinuses. These include taking cultures or biopsies, managing epistaxis and performing functional endoscopic sinus surgery.

Zero degree scope

Easiest to manoeuvre , gives a head on straight view

Thirty degree scope

Used to visualize structures that are not in direct line of sight, especially important in seeing lateral nasal wall, skull base and the FR.

Forty five, seventy and ninety degree scope

Used to visualize the challenging FR and maxillary sinus pathology

Graded Endoscopic Approaches to The Frontal Recess

The Frontal recess surgeries were classified by Dr.Draf as :

Type I,

Type IIa and Type IIb,

Type III

Type I

When there is no disease in the frontal recess and the disease is limited to the ethmoids, the recommended approach would be a Type I Draf .This is done endonasally by first doing an ethmoidectomy which includes the cell septa in the region of FR. The inferior part of the FR along with its mucosa is not traumatized for fear of developing a stricture. Doing this procedure is helpful when there is only minimal disease in the FS, and the patient does not have any risk factors like asthma and aspirin intolerance.

It is because these risk factors cause the nasal mucosa to have an inferior quality and thus cause unpredictable results. It is seen that in majority of cases the FS heals spontaneously as a result of better drainage.

<u>Type IIa</u>

Type II can be divided into two types, Type IIa and Type IIb. When the frontal recess is involved with disease, the Type IIa Draf forms the basic endoscopic approach, especially when the entire frontal recess cells are located below the frontal beak. When there are cells above the frontal beak, the determining factor would be which approach to be adopted to get the proper access to these cells. Although a Type IIa approach may be sufficient, in these cases one may have to occasionally consider Type IIb or Type III Draf procedure in order to completely address these cells. In this procedure, the floor of the frontal sinus lying between the LP and the MT is resected.

<u>Type IIb</u>

In this procedure, the floor of the FS between LP and the nasal septum anterior to the ventral margin of the olfactory recess is resected.

<u>Type III: Endonasal median drainage</u>

This is performed when the cause of chronic frontal sinusitis is either bone or dense scar from prior surgery which obliterates the communication of the FS to the nasal cavity. One way to restore drainage is to resect the entire floor of both the FS's. This procedure is called as type III frontal sinusotomy.

The components of type III surgery are resection of the entire floor of both FS’s, the intersinus septum which separates the FS into two cavities and the upper part of the nasal septum. In order to achieve the optimal opening of the FS, it is helpful to identify the olfactory fibers bilaterally. The MT is exposed and resected in an anterior to posterior direction along its origin at the level of the skull base. After resecting about 5 millimetre, the olfactory fibers can be visualised. This step is repeated on the other side as well which will result in a so called "frontal T".

In cases of revision surgery, type III drainage can begin from either of two sides, lateral or medial. The lateral approach is usually done in cases where the previous ethmoidal surgery was incomplete and the MT is still seen which can be used as a landmark. The medial approach is justified if previous ethmoidal surgery was complete, and the MT is totally absent. A medial approach starts with the partial removal of the perpendicular plate of ethmoid which is followed by identification of the olfactory fibers on both sides.

In this study we review the approaches for a Type IIa Draf, based on the following anatomical structures :

1) Skull Base - Wigand’s technique

2) Agger nasi – Axillary flap technique

3) Uncinate Process – Uncapping the egg

4) Bullae Ethmoidalis – Intact Bullae technique

Wigand's Technique (Postero Anterior method) [57]

Wigand's technique is the gold standard as this is the most reliable technique in revision surgery with extensive polyposis. This technique depends on fixed landmarks and hence it can be done when the frontal sinus drainage pattern is not recognizable on the pre-operative scans. Hence this technique is very useful in extensive diseases. However this technique may not be indicated in limited diseases where the drainage pathway is recognizable.

The prerequisite for this approach is removal of the anterior part of the ethmoid upto the base of the skull. If these anterior ethmoid cells have been opened, a blunt probe will glide smoothly into the frontal infundibulum. In case the frontal duct is not identified, the transverse bar formed by the anterior ethmoidal artery is identified and anteriorly the frontal sinus pathway is identified.

The following are the landmarks for fenestration via the anterior ethmoid cells :

- The bulge formed by the AEA
- The medial lamella of the middle turbinate at its' central insertion into the ethmoid roof after resection of the agger nasi cell
- The orbital wall

Axillary Flap Method [40]

This method which was popularized by P.J.Wormald, is an excellent method when the drainage pathway is recognizable. This method along with building block analysis of the frontal recess anatomy enables the surgeon to have a very clear picture about how to systematically remove the individual frontal recess cells. This technique can be used even in extensive disease as long as the frontal sinus drainage pathway can be recognized on pre-operative scans.

The main idea is to understand and predict the 3-Dimensional anatomical structure and FS drainage pathway. This will help in creating a surgical plan for each cell step by step before actually performing the procedure. This 3-D planning should ideally take place before any surgical procedure is done on the patient. Each step has to be worked through intelligently, be it involving the opening or fracturing of a cell or guiding of a probe or even a curette along the FS drainage pathway.

This should proceed till the identification of the subsequent cells upto a level where every cell is cleared and the frontal ostium is clearly located.

According to PJ Wormald, The surgeon should be thorough in analysing the radiological anatomy from multislice CT scans and develop a 3-Dimensional orientation of the FR along with its'drainage pathway, and should thereafter develop a step by step plan for each cell. This allows for a safer and better dissection of the FR. If a case is approached in this manner, this dissection will help in minimizing mucosal trauma and also improve healing in this region and prevent scarring .

According to Wormald, the surgeon should not begin with this technique without experience with these 3-Dimensional reconstructions on complex anatomy and he should begin this process with simple straight forward anatomical configurations and progressively go to the more complex higher configurations. (Fig.18)

The first step in the surgery involves exposure of the anterior surface of the ANC by elevating an axillary flap.[40] Thereafter, the anterior wall of the ANC is removed, and the ANC is reached. A curette is now placed behind the posterior wall and roof and the ANC is removed completely.

This procedure allows viewing the IFSSC opening and the drainage pathway of the frontal sinus. A probe is then slid along into the presumed FS drainage pathway and gently advanced superiorly without pressure which helps in confirming the drainage pathway. Thereafter, this pathway is adequately widened so as to accomodate a suction curette, which is subsequently placed into this pathway and helps in viewing the frontal ostium.

The IFSSC (if present) lumen is located, and its' lateral wall is removed by combining use of a curette and giraffe forceps. This helps to further widen the natural ostium of the FS. In cases where there is doubtfulness with respect to the position of the FS drainage pathway, a FS mini-trephine can be inserted and the FS irrigated with a dye like fluorescein-stained saline. This dye can be visualized as it trickles out of the FS drainage pathway. Now an instrument like a probe or curette can be slid along the drainage pathway tracing dyed saline into the FS.

Uncapping The Egg [33]

This technique which was popularised by Stammberger is based on the attachment of the uncinate process and can technically be helpful when the cells are located below the frontal beak. The presence of the cells above the frontal beak will alter the drainage pathway superiorly and hence relying on this technique alone may not be useful when such cells are present. Therefore this technique may be relied upon in limited diseases with the pneumatisation primarily being below the frontal beak.

Prior to the surgery, it is important to analyse the frontal and ethmoidal region with conventional 3- mm coronal plane CT cuts, giving more attention to the anatomy of the UP, especially its' superior attachment. In instances where a CT is inadequate, continuous cut by cut tracking of image-guided photographs give better visualization of the UP. Utilizing an image-guided set up in preoperative planning also provides additional sagittal cuts, which are very important to study the frontal sinus outflow tract (FSOT). Doing this, helps the surgeon to efficiently plan the meticulous approach to the frontal sinus and predict the complexity in approaching the surgery.

The initial few steps of the surgery are done using a zero degree nasal endoscope. The first surgical step involves displacement of the MT medially using a freer elevator. The UP is located and medialised. Thereafter, the removal of the uncinate process and frontal ESS is performed using microdebrider. The inferior portion of the UP which is visualised is totally removed with a forty degree curved microdebrider. Now at this juncture, if the maxillary sinus (MS) ostium is not involved with disease, it is not addressed.

In the majority of cases, after the removal of the inferior portion of the UP is obtained, one will notice a structure which appears like a dome and looks similar to an inferiorly opened anterior ethmoid cell. This structure is called the terminal recess (RT) and is the superior blind end of the ethmoidal infundibulum. The RT is formed by the superior insertion of the UP to the LP. It is common for surgeons to mistakenly identify the RT as an ANC, or even a frontal sinus (FS), especially in cases where the recess is placed high.

For descriptive purpose, the RT has an anterior and a posterior wall. If a frontal seeker is inserted postero-medially to the posterior wall and thereafter radvanced superiorly, the upper end of the instrument will usually enter the frontal sinus. However, this step is rarely necessary as exact location of the frontal sinus (FS) can be predicted and visualized by following and resecting the UP. Following this, the endoscope is changed to an angled scope and the curved microdebrider is utilized to completely resect the anterior wall of the RT until the instrument reaches the lacrimal bone, just lateral to its junction with the MT and medial to the LP.

The posterior wall of the RT is widely exposed and thereafter traced superiorly and removed until resection of the superior attachment of the UP is achieved. This last step is usually sufficient to obtain adequate exposure of the FS. Sometimes, only the posterior wall of the FS is exposed, making it imperative to resect the postero-medial wall of a well-pneumatized ANC in order to obtain better view of the FS. Very often FC's need to be opened in order to achieve clear access to the FS. Because the RT and the ANC share the same common posteromedial wall, removal of the ANC is similar to the removal of the RT posterior wall, just a bit more superior and anterior.

Resection of the anteriorly placed ANC or FC is safe because it is located away from the orbit and brain. This is usually accomplished with a sixty degree microdebrider which is very helpful in opening these cells. If the steps are followed as described, the frontal ostium (FO) is usually found to be quite wide, with an approximate antero-posterior (A-P) diameter of seven millimetre and a transverse- diameter (T-D) of nine mm.

Even though the superior part of the frontal recess (FR) is higher and narrower, the surgery in this region is done with the same instruments, ie, thirty degree or forty five degree endoscopes and forty degree curved microdebrider. A sixty degree blade can also be useful for surgery in this region .

In cases where the UP inserts superiorly to the base of the skull or to the MT, frontal sinus (FS) exposure is immediately obtained as the ethmoidal infundibulum and the FS share one common compartment. Here there is no RT, and therefore the FS will be exposed soon after resecting the superior part of the visible UP. In these situations, operating medial to the superior insertion of the UP is dangerous and may cause perforation of the thin lateral lamella of the CP.

At times, it is necessary to resect the posterior portion of a well-pneumatized ANC or FC to achieve better view of the FS.[50] In cases where FC's or SOEC's are present, then the common wall between the FS and the cell has to be removed as high into FR as possible because, if this is not done adequately removed, then they can become chronically edematous as a result of disruption of mucociliary clearance and then resulting in FS obstruction.

Disruption of mucociliary flow patterns in inadequately cleared cells in turn leads to mucus retention and edema, which may seal off the frontal sinus outflow tract.[51] Resection of the common wall may be achieved with a sixty degree microdebrider, but a FS curette along with a giraffe forceps may at times be required to reach the highly placed bony wall.

Type 3 FC's and Type 4 FC's could be difficult to deal with and can be unreachable endoscopically. Here, in such conditions, an external FS approach can be taken up to work on the FR along with intranasal dissection or one has to proceed with type IIb or type III Draf surgery. Checking of an open FS is achieved by transillumination with a thirty degree endoscope or by using an image guided system. The endoscope need not enter the FS. If the FS is widely opened, placing the endoscope in the FR below the FO will produce a brightly illuminant red signal over the patient's forehead. The resulting intensity of transillumination is inversely related to the extent of FS disease.

However, the presence of transillumination will not confirm an open FS (false positive) as light may transilluminate via thin bony plates or even polyps. But otherwise, the absence of this transillumination indicates that the FS is not opened adequately; either the illuminated cell is a highly placed RT, ANC, or the FS is obstructed by disease, or the sinus may be hypoplastic.[52]

At the end of frontal recess surgery, the rest of the endoscopic procedure is performed as situation warrants. It is very important to keep the area in between the anterior ethmoid roof and the posterior wall of the FS smooth to prevent the formation of scar tissue and result in stenosis. This is the reason why the ethmoid bulla along with its superior attachment are completely resected.

In many patients, the AEA is clearly located and preserved. The MT is almost always preserved. Using the straight microdebrider blade, medialization of the MT is obtained by removing small areas of the mucosal surfaces along the medial surface of the MT and the opposing septum. The MT is pushed medially with the help of a long nasal speculum, before using absorbable packing like merogel in the ethmoidal cavity to help preserve the MT position.[53]

This manoeuvre causes controlled fibrosis and subsequent synechia formation between the MT and the nasal septum. It has to be remembered that medialization of the MT and meticulous care of the MT’s lateral surface are very important to prevent lateralization which has the potential result of FR obstruction.[54]

Intact Bullae Technique [44]

This was initially described by Mark Lourie and popularized by D.S.Sethi, is based on the fact the attachment of bullae ethmoidalis to the skull base will protect the anterior ethmoidal artery from iatrogenic trauma. However this technique can be used only when the bullae ethmoidalis attaches to the skull base which is not the case usually. Supra bullar recess is more common and hence this technique has a limited application in frontal sinus surgery.

The first step that is followed in the dissection is creation of an infundibulotomy at the attachment of the UP along the posterior margin of the lacrimal fossa. The next manoeuvre is to extend it into the anterior wall of the agger with a sicke knife. Following this, removal of the anterior wall of the agger is done which is most easily accomplished with a right angle forceps.

Once the anterior wall of the agger is completely resected, the lamella of the middle turbinate extending superiorly and inserting onto skull base can be visualized. It should be known that it is easy to mistake a large supraorbital cell for the frontal sinus os which is usually more medially located.

The next step in the dissection is removal of the tissue and bone just lateral to the middle turbinate lamella. The bulla also defines the posterior margin of the frontal sinus opening. Further resection of the region anterior to the frontal os yields wide exposure into the frontal sinus. Sometimes, when the anterior wall of the agger cannot be removed because it is too thick or the agger is poorly pneumatised, the frontal os cannot be approached directly.

Modifications in such scenario include use of 30^0 or 70^0 endoscopes to visualize removal of the posterior agger wall with angled grasping forceps. If there is a hypertrophic bulla which is preventing instrument placement into the frontal recess, then it is partially resected, leaving the superior portion attached to skull base.

In cases where the anterior wall of the bulla is absent consequent to resection, disease, or anatomic variability, the frontal os can be found just lateral to the middle turbinate and anterior to the anterior ethmoidal artery, and or the ethmoid dome. Anterior to the ethmoidal artery is an oval or triangular area formed by either a suprabullar cell or the superior extent of the bulla itself.

The frontal os is usually located anterior to this oval area and just lateral to the insertion of the middle turbinate onto the base of the skull. Removal of the anterior agger nasi wall disrupts anterolateral attachment of the middle turbinate which might result in possible formation of adhesions between the middle turbinate and agger or frontal recess. This complication can be minimized by maintaining intact mucosal surfaces on the adjacent portion of the middle turbinate and unresected lateral portion of the agger nasi. Additionally gelfilm or silastic sheets can be interposed between the lateral wall and middle turbinate for 7 to 10 days.

In instances, when the mucosa appears reversibly diseased, it is usually not advisable to resect it unless it is attached to a bony partition which would otherwise be removed during the operation. By maintaining intact mucosa, less granulation tissue seems to form with less subsequent fibrosis and contracture.

Features like asymmetry of the ethmoid roof, keros classification, topography of the skull base are important features to be analysed on computerised tomography scans before surgery in order to minimize iatrogenic trauma to the skull base.

Asymmetry of the Ethmoid Roof

The roof of the FR is formed by the fovea ethmoidalis. This is a continuation of the orbital plate of the frontal bone. This bone is relatively thick and is quite resistant to penetration and separates the ethmoid air cells from the anterior cranial fossa. Medially it articulates with the thin bone of the lateral lamella of the cribriform plate and rises like a dome above it.[20]

Inadvertent violation of the fovea ethmoidalis or cribriform plate with intracranial injury and or cerebrospinal fluid (CSF) leak is among the most serious potential complications of endoscopic sinus surgery.

In one study by Floreani et al [43,] they found that the right fovea ethmoidalis was higher than the left in 59% of patients.

In a study by Richard et al [21] in a retrospective review of coronal CT scans, in 9.5%, there was an asymmetry between the height of the fovea ethmoidalis on the right and left sides. Of these, 63.2% were lower on the right side, whereas 36.8% were lower on the left. (Fig.19)

Keros classification

Keros devised a classification of the olfactory fossa based upon the position of the cribriform plate (CP) in relation to the ethmoid roof, and this classification has surgical relevance during ESS.

In the type I, the CP is 1–3 mm deep, the corresponding lateral lamella (LL) is short and this causes a significant portion of frontal bone to protect the ethmoid roof, making the roof thicker and the sinus less prone to iatrogenic trauma during ESS. In the type II, the CP is 3–7 mm deep, and the corresponding LL forms a considerable part of the medial ethmoid roof. In the type III, the CP is 7–16 mm deep and the roof lies at a significant level above the CP. (Fig. 20)

The thin lateral lamella (LL) forms a huge part of the ethmoid roof, which is not guarded by the thick frontal bone. This makes the Keros type III the most vulnerable type and is therefore considered to pose a major risk for iatrogenic trauma involving the CP during ESS.

In a study by Mohammad et al [22] Keros type I was seen in 46 sides (29.8 %), type II in 75 sides (48.7%) and type III was seen in 33 (21.4%) sides.

Keros type I was seen in 38 sides in males and 8 sides in females. Type II was seen in 46 and 29 sides in males and females, respectively. Type III was seen in 18 sides in males and in 15 sides in females.

MATERIALS AND METHODS

A detailed research proposal of the study was forwarded to the institutional review board of the Christian medical college and approval obtained. It was a retrospective and prospective case control study. Fifty controls and fifty cases were studied from Nov 2012 to Oct 2013. Controls and cases were randomly selected.

Controls

Patients who underwent axial CT scan of temporal bone with 1mm cuts for non sinus disease like :

- chronic suppurative otitis media
- CSF rhinorrhoea
- Fracture temporal bone,

with absence of significant sinonasal symptoms as established by chart reviews. The analysis was done retrospectively. CT scans of these patients were retrieved from PACS (Picture Archival and Communication System). Sagittal, coronal and axial reconstructed images of the frontal recess region were created using a specific workstation. The scans were then reviewed with the help of a radiologist.

Cases

Patients' with a clinical diagnosis of chronic frontal sinusitis based on the following inclusion criteria :

Patients of age between 15-65 years with 12 weeks or more of signs and symptoms suggestive of frontal rhinosinusitis with two major factors or one major factor and two minor factors and or nasal purulence on examination.

Major criteria

1. Facial pain or pressure
2. Nasal obstruction or blockage
3. Nasal discharge or purulence or discoloured postnasal discharge
4. Hyposmia or anosmia

Minor criteria

1. Headache
2. Fever
3. Halitosis
4. Fatigue
5. Dental pain
6. Cough
7. And ear pain, pressure or fullness

Frontal sinusitis was diagnosed when the sinus had mucosal thickening > 3 mm on CT scan, either involving the entire sinus or the dependent area of the sinus.

Exclusion criteria

1. Clinically proven allergy
2. Nasal mass/malignancies/extensive nasal polyposis

3. Previous history of sinonasal surgeries
4. Fungal sinusitis
5. Acute frontal sinusitis

<u>Method of collection of data</u>

The cases were given an information sheet and also verbally explained about the study and procedures in the language of understanding and informed consent was obtained.

Subsequently, a detailed history was elicited and a clinical examination performed followed by a diagnostic nasal endoscopy.

A computerized tomography scan was performed of the paranasal sinuses and the images were reconstructed in 3 dimensional format using a specific workstation and were reviewed with the help of a radiologist.

The Frontal sinuses (200) were also further divided into diseased and non-diseased based on the radiological findings and compared.

The findings were documented and analysed using Stata/IC 10.1 software package. The descriptives were given as frequencies and percentage, mean along with the standard deviation. Student 'T' test was used to compare the means and Chi-square statistics was used to test the association between the variables.

Wilcoxon rank-sum (Mann-Whitney) test was done to see the difference between two groups when the data was not normally distributed.

RESULTS

These were the results of Frontal Recess Anatomy – Radiological Study and its' Surgical Implications.

A total of 100 subjects (200 frontal sinuses) were analysed.

Demographic Data

In this study, males constituted 60% of the subjects and the remaining 40% were females. Age group ranged from 17 to 76 years

The following tables are the association between cases and controls. If the p-value is < 0.05, it indicates the association or difference in proportion among two variables. The first row in the table are counts and the second row are frequencies.

1. Frontal Sinus

Group	Normal	Hypoplastic	Hyperplastic	Total
Control	91 91.00	3 3.00	6 6.00	100 100.00
Case	93 93.00	1 1.00	6 6.00	100 100.00
Total	184 92.00	4 2.00	12 6.00	200 100.00

P = 0.600

Table 1 - In all, 184 (92%) sinuses were normal, 4 (2%) were hypoplastic and 12 (6%) were hyperplastic.

2. <u>Frontal Recess</u>

Group	Normal	Obstructed	Total
Control	100 100.00	0 0.00	100 100.00
Case	63 63.00	37 37.00	100 100.00
Total	163 81.50	37 18.50	200 100.00

P=0.000

Table 2 - Amongst the cases, 37 (37%) frontal recess' were obstructed

3. <u>Frontal Sinus Disease</u>

Group	No disease	Partial opacification	Total opacification	Total
Control	100 100.00	0 0.00	0 0.00	100 100.00
Case	21 21.00	72 72.00	7 7.00	100 100.00
Total	121 60.50	72 36.00	7 3.50	200 100.00

P= 0.000

Table 3 - Amongst the cases, 72% of the sinuses had partial opacification and 7% had total opacification of the frontal sinus.

4. <u>Agger Nasi cell</u>

Group	Absent	Present	Total
Control	6 6.00	94 94.00	100 100.00
Case	8 8.00	92 92.00	100 100.00
Total	14 7.00	186 93.00	200 100.00

P = 0.579

Table 4 - Overall, 186 (93%) sides had ANC's. Controls had 94% and cases had 92% agger nasi cells.

5. <u>Bullae ethmoidalis superior attachment</u>

Group	Superiorly Dehiscent	Superiorly Attached	Total
Control	63 63.00	37 37.00	100 100.00
Case	49 49.00	51 51.00	100 100.00
Total	112 56.00	88 44.00	200 100.00

P = 0.046

Table 5 - Overall, 112 bullae (56%) were dehiscent and 88 (44%) of the bullae were attached to the skull base.

6. **Frontal cells**

Group	No cell	Type 1	Type 2	Type 3	Type 4	Total
Control	44 44.00	26 26.00	13 13.00	17 17.00	0 0.00	100 100.00
Case	42 42.00	41 41.00	1 1.00	14 14.00	2 2.00	100 100.00
Total	86 43.00	67 33.50	14 7.00	31 15.50	2 1.00	200 100.00

P = 0.003

Table 6 - Overall, frontal cells were absent in 43%, **Type 1** – 33.50%, **Type 2** – 7%, **Type 3** – 15.50%, **Type 4** – 1%

7. **Frontal bullar cells**

Group	Absent	Present	Total
Control	85 85.00	15 15.00	100 100.00
Case	92 92.00	8 8.00	100 100.00
Total	177 83.50	23 11.50	200 100.00

P = 0.121

Table 7 - FBC's were present in 23 (11.50%) of the sinuses and absent in 177 (83.50%) of them.

8. Suprabullar cells

Group	Absent	Present	Total
Control	31 31.00	69 69.00	100 100.00
Case	53 53.00	47 47.00	100 100.00
Total	84 42.00	116 58.00	200 100.00

P = 0.002

Table 8 - Suprabullar cells were present in 116 sinuses (58%) and absent in 84 (42%)

9. Suprabullar recess

Group	Absent	Present	Total
Control	67 67.00	33 33.00	100 100.00
Case	84 84.00	16 16.00	100 100.00
Total	151 75.50	49 24.50	200 100.00

P = 0.005

Table 9 - Suprabullar recess was present in 49 sides (24.50%) and absent in 151 (75.50%)

10. <u>Supraorbital ethmoidal cell</u>

Group	Absent	Present	Total
Control	65 65.00	35 35.00	100 100.00
Case	68 68.00	32 32.00	100 100.00
Total	133 66.50	67 33.50	200 100.00

P = 0.653

<u>Table 10</u> - Overall, Supraorbital cells were present in 67 (33.50%) sides and absent in 133 (66.50%) sides.

11. <u>Interfrontal cell</u>

Group	Absent	Present	Total
Control	88 88.00	12 12.00	100 100.00
Case	81 81.00	19 19.00	100 100.00
Total	169 84.50	31 15.50	200 100.00

P = 0.171

<u>Table 11</u> - Interfrontal cells were present in 31 sides (15.50%) and absent in 169 sides (84.50%)

12. <u>Depth of Olfactory Fossa</u>

Group	Type 1	Type 2	Type 3	Total
Control	17 17.00	81 81.00	2 2.00	100 100.00
Case	22 22.00	78 78.00	0 0.00	100 100.00
Total	39 19.50	159 79.50	2 1.00	200 100.00

P=0.260

<u>Table 12</u> - Keros' **Type 1** – 19.50 % ,**Type 2** – 79.50%, **Type 3** – 1%

13. <u>Topography – Lowest Level of Anterior skull base</u>

Group	Sphenoid	Posterior ethmoid	Total
Control	62 62.00	38 38.00	100 100.00
Case	67 67.00	33 33.00	100 100.00
Total	129 64.50	71 34.50	200 100.00

P = 0.460

<u>Table 13</u> - Sphenoid was lower in 129 sides (64.50%) and posterior ethmoid was lower in 71 sides (34.50%)

14. Uncinate process superior attachment

Type of Attachment	Frequency	Percent (%)
Not made out	15	7.50
Type 1	63	31.50
Type 2	51	25.50
Type 3	40	20.00
Type 4	1	0.50
Type 5	20	10.00
Type 6	10	5.00
Total	200	100.00

Table 14 - Overall, majority had Type 1 (31.50%) attachment and least was Type 4 (0.50%) attachment

15. Antero Posterior Diameter of Frontal Ostium

Group	Observed	Mean (mm)	Standard Deviation
Control	100	5.77	2.49
Case	100	6.80	2.25
Total	200	6.29	2.42

P = 0.0024

Table 15 - Mean AP diameter was 6.29 +/- 2.42 mm

16. Transverse Diameter of Frontal Ostium

Group	Observed	Mean (mm)	Standard Deviation
Control	100	6.04	2.10
Case	100	6.72	2.22
Total	100	6.38	2.18

P=0.0289

Table 16 - Mean Transverse diameter was 6.38 +/- 2.18 mm

17. Area of Frontal Ostium

Group	Observed	Mean ($mm^{2)}$	Standard Deviation
Control	100	27.42	17.57
Case	100	36.50	18.63
Total	200	31.96	18.63

P=0.0005

Table 17 - Mean area of frontal ostium was 31.96 +/- 18.63 mm^2

18. Anterior Ethmoidal Artery – Grades

Group	Grade 1	Grade 2	Grade 3	Total
Control	12 12.00	30 30.00	58 58.00	100 100.00
Case	20 20.00	29 29.00	51 51.00	100 100.00
Total	32 16.00	59 29.50	109 54.50	200 100.00

P=0.291

Table 18 - Grade 1 was found in 16%, Grade 2 in 29.50%, Grade 3 in 54.50%

19. Asymmetry of ethmoidal roof

Type	Frequency	Percent (%)
Bilateral equal	40	20
Asymmetry –rightlower	116	58
Asymmetry – left lower	44	22
Total	200	100

Table 19 - Right side was lower in 116 (58%) sides and left lower in 44 (22%) of sinuses. Both were equal height in 40 (20%) sinuses.

<u>The Frontal sinuses were divided into diseased and non diseased and compared. Out of the total 200 sinuses, diseased sinuses (79) were compared with normal sinuses (121)</u>

1. **<u>Frontal sinus</u>**

Group	Normal Size	Hypoplastic	Hyperplastic	Total
Normal	111 91.74	4 3.31	6 4.96	121 100.00
Diseased	73 92.41	0 0.00	6 7.59	79 100.00
Total	184 92.00	4 2.00	12 6.00	200 100.00

P=0.205

<u>Table 20</u> - In the diseased sinuses, 73 (92.41%) were normal in size and 6 (7.59%) were hyperplastic. In the normals, 111 (91.74%) were normal sized, 4 (3.31%) were hypoplastic and 6 (4.96%) were hyperplastic.

2. **<u>Agger nasi cell</u>**

Group	Absent	Present	Total
Normal	6 4.96	115 95.04	121 100.00
Diseased	8 10.13	71 89.87	79 100.00
Total	14 7.00	186 93.00	200 100.00

P = 0.161

<u>Table 21</u> - ANC's were present in 115 (95.04%) of normal sinuses and 71 (89.87%) of diseased sinuses.

3. **Frontal Bullar cell**

Group	Absent	Present	Total
Normal	106 87.60	15 12.40	121 100.00
Diseased	71 89.87	8 10.13	79 100.00
Total	177 88.50	23 11.50	200 100.00

P = 0.623

Table 22 - FBC's were present in 15 (12.40%) of normal and 8 (10.13%) of diseased sinuses

4. **Frontal cells**

Group	Type 1	Type 2	Type 3	Type 4	Total
Normal	39 52.00	13 17.33	23 30.67	0 0.00	75 100.00
Diseased	28 71.79	1 2.56	8 20.51	2 5.13	39 100.00
Total	67 58.77	14 12.28	31 27.19	2 1.75	114 100.00

P= 0.011

Table 23 - In Normals, type 1 – 39 (52%), type 2 – 13 (17.33%), type 3 – 23 (30.67%) , type 4 – 0%. In diseased, type 1 – 28 (71.79%) , type 2 – 1 (2.56%), type 3 – 8 (20.51%), type 4 - 2 (5.13%)

5. Suprabullar cell

Group	Absent	Present	Total
Normals	45 37.19	76 62.81	121 100.00
Diseased	39 49.37	40 50.63	79 100.00
Total	84 42.00	116 58.00	200 100.00

P = 0.088

Table 24 - Suprabullar cells were present in 76 (62.81%) of normals and 40 (50.63%) of diseased sinuses.

6. Supraorbital ethmoidal cell

Group	Absent	Present	Total
Normal	80 66.12	41 33.88	121 100.00
Diseased	53 67.09	26 32.91	79 100.00
Total	133 66.50	67 33.50	200 100.00

P = 0.887

Table 25 - SOEC's were present in 41 (33.88%) of normal and 26 (32.91%) of diseased sinuses.

7. <u>Interfrontal cells</u>

Group	Absent	Present	Total
Normal	104 85.95	17 14.05	121 100.00
Diseased	65 82.28	14 17.72	79 100.00
Total	169 84.50	31 15.50	200 100.00

P = 0.483

<u>Table 26</u> - Interfrontal cells were present in 17 (14.05%) of normal and 14 (17.72%) of diseased sinuses.

8. <u>Uncinate Process superior attachment</u>

Group	Medial drainage	Lateral drainage	Total
Normal	101 84.17	19 15.83	120 100.00
Diseased	53 81.54	12 18.46	65 100.00
Total	154 83.24	31 16.76	185 100.00

P = 0.648

<u>Table 27</u> - Medial drainage was present in 101 (84.17%) of normals and 53 (81.54%) of diseased sinuses. Lateral drainage was present in 19 (15.83%) of normal and 12 (18.46%) of diseased sinuses.

9. Antero - Posterior Diameter

Group	Number	Mean (mm)	Standard Deviation
Normal	121	5.82	2.45
Diseased	79	7.01	2.2

P=0.0001

Table 28 - Mean AP diameter in normals was 5.82 +/- 2.45 mm and in diseased sinuses was 7.01 +/- 2.2 mm

10. Transverse Diameter

Group	Number	Mean (mm)	Standard Deviation
Normal	121	6.02	2.15
Diseased	79	6.93	2.13

P = 0.0039

Table 29 - Mean Transverse diameter in normal was 6.02 +/- 2.15 mm and in diseased was 6.93 +/- 2.13 mm

10. Area of Frontal Ostium

Group	Number	Area ($mm^{2)}$	Standard Deviation
Normal	121	27.74	17.34
Diseased	79	38.44	18.78

P= 0.0000

Table 30 - Mean area of the frontal ostium in normal was 27.74 +/- 17.34 mm^2 and in diseased sides was 38.44 +/- 18.78 mm^2

DISCUSSION

Although a lot of literature about frontal recess anatomy is appearing in the western studies, there is paucity of Indian studies on this subject. In this study we tried to record the main variations in the anatomy of the frontal recess using three dimensional computerized tomography in patients who are suffering from chronic sinusitis and compared them with normal sinuses, therefore trying to find out if any particular pneumatisation pattern predisposes to the development of chronic frontal sinusitis.

Most of the studies on multiplanar computed tomographic ananlyis of frontal sinus outflow tract have been done in patients with no sinusitis or in patients with chronic sinusitis.

Prevalence of frontal cells and other anatomic variants was studied by Meyer et al [42] in 768 coronal CT scans.

Multiplanar reconstructed tomography was utilized and the frontal recess was studied by Kew et al [10] with regard to depiction and understanding the anatomy in deciding the surgical approach in 43 patients.

Lee et al [11] reported their findings on the frontal sinus pneumatisation in 50 patients who had no frontal sinus disease, where they used 3 dimensional reconstruction computerized tomography.

A study on the relationship of frontal cells to frontal sinusitis was done by Del Gaudio et al [19] in 106 patients using multiplanar CT.

However, literature search did not show any comparative study from centres in India regarding frontal sinus outflow tract in patients without sinusitis and in patients with sinusitis.

In this study, frontal recess was studied in 50 patients without sinusitis and compared with 50 patients with sinusitis using multiplanar computed tomography.

Out of the 200 frontal recess examined, 121 had disease and 79 were normal. The study group included 60 males and 40 female patients. Age group was between 17 and 76 years.

Frontal sinus

Majority (92%) of the frontal sinus' examined were normal in size. Only 2% were hypoplastic and 6% were hyperplastic. There was no significant difference in size between the diseased and normal sinuses.

Agger Nasi Cells

In Lee's study [11] on patients' without sinusitis, the prevalence of agger nasi cells was 89%.

Meyer [42] showed that they were present in 86.7% of patients with sinusitis.

Val Alyea had reported it as 89% and recently Bolger [1] reported its' incidence as 98.5%.

In our study, we found that 93 % sides had agger nasi cells. There was no significant difference between the diseased and normal sinuses. Our findings were similar to Del

Gaudio's study [19] where there was no association between agger nasi cells and frontal sinusitis.

Frontal cells

In Meyer's study [42] the prevalence of frontal cells was 20.4%

Type 1 – 14.9%

Type 2 – 3.1%

Type 3 – 1.7%

Type 4 – 2.1%

According to Lee's [11] finding,

Type 1 – 37%

Type 2 – 19%

Type 3 – 8%

Type 4 – 0%

Delgaudio [19] reported 33% prevalence in his multiplanar reconstructed study of 106 patients.

Type 1 – 18.4%

Type 2 – 2%

Type 3 – 6.1%

Type 4 – 3.1%

Van Alyea [55] found 40% frontal cells in his report. Kuhn [15] in his study and Lien et al [23] in his study found positive corelations between frontal cells and frontal sinusitis.

However Del Gaudio [19] , did not find any significant correlation.

In our study , frontal cells were present in 57% of the sides

Type 1 – 33.50%

Type 2 – 7%

Type 3 – 15.50%

Type 4 - 1%

These findings were similar to previous studies, type 1 frontal cells were the most common and type 4 cells were the least common.

However like Del Gaudio's study [19] , we did not find a significant relation of frontal cells to sinusitis. ($p = 0.011$)

Frontal Bullar cells, Suprabullar cells, Supraorbital ethmoidal cells, and interfrontal septal cells

Walter Lee et al [11] reported the prevalence of frontal bullar cells, suprabullar cells, supraorbital ethmoidal cells and interfrontalseptal cells using 3 dimensional computer tomography as follows

Frontal Bullar cell – 9%

Suprabullar cell – 15%

Supraorbital ethmoidal cell – 62%

Interfrontal sinus septal cell – 14%

Del Gaudio [19] reported the prevalence of interfrontal septal cells on multiplanar computed tomography as 12.20%.

Lien et al [23] in their study concluded that frontoethmoid cells posterior and posterolateral to the frontal recess (SBC's, FBC's, and SOEC's) might reveal a more significant association with the development of frontal sinusitis than the cells anterior to the frontal recess (ANC's, FC's 1–3). In addition, the presence of SOEC's on CT images might indicate the highest odds of frontal sinusitis, followed by the presence of SBC's, FBC's, and Recessus Terminalis.

Sedaghat et al [18] , in their study found a statistically significant association between the presence of frontal intersinus cells (OR = 18.37) with development of chronic rhinosinusitis on both univariate and multivariate logistical regressions.

In this series,

Frontal bullar cells – 11.50%

Suprabullar cells – 58%

Supraorbital cells – 33.50%

Interfrontal sinus septal cells – 15.50%

Unlike the above mentioned studies, we did not find a significant association of FBC’s, SBC’s, SOEC’s or IFSSC’s in relation to frontal sinusitis. ($p>0.05$)

Superior Attachment of Uncinate Process

Turgut et al [17], reported the prevalence of superior attachment of attachment in 361 sides as follows :

Type 1,2 – 63%

Type 3 – 3%

Type 4 – 12%

Type 5 – 14%

Type 6 – 8%

Lansberg et al [4] reported the following types of uncinate process’s superior attachment.

Type 1: insertion to the lamina papyracea (52%).

Type 2: insertion to the posteromedial wall of the agger nasi cell (18.50%).

Type 3: insertion to both the lamina papyracea and the junction of the MT with the CP (17.50%).

Type 4: attachment to the junction of the middle turbinate with the cribriform plate (7%).

Type 5: insertion to the skull base (3.60%).

Type 6: insertion to the middle turbinate (1.40%).

In our series,

Superior attachment not made out in 7.50%

Type 1 - 31.5%

Type 2 - 25.5%

Type 3 – 20%

Type 4 - 0.50%

Type 5 – 10%

Type 6 – 5%

Similar to previous studies, type 1/2 was the commonest type (attaching to lamina papyracea), but contrary to other studies, the rarest type was type 4 (insertion to the junction of the middle turbinate with the cribriform plate).

Turgut et al [17] found medial drainage of frontal sinus in relation to uncinate attachment in 66% and lateral drainage 35% and they also found a higher relation of frontal sinusitis to medial drainage of frontal sinus in relation to uncinate attachment.

In our study, Medial drainage was found in 83.24 % and lateral type drainage was found in 16.76%. Unlike Turgut et al [17], we did not find a significant relationship while comparing the medial type of drainage and its' association with frontal sinusitis.

<u>Diameter and area of frontal ostium</u>

Landsberg et al [4] in their study reported the dimensions of the frontal ostiumas follows A-P diameter was 7.22 mm with a SD of 2.78 mm and T-D was 8.92 mm with a SD of 2.95 mm. The mean sectional frontal ostium area was 50.5 mm ^{2}.

Del Gaudio et al [19] reported that there was no significant association between the area of the frontal isthmus and the occurence of chronic frontal sinusitis.

In our series, Mean AP diameter was 6.29 +/- 2.42 mm, Mean Transverse diameter was 6.38 +/- 2.18 mm, Mean area of frontal ostium was 31.96 +/- 18.63 mm^2. We did not find a smaller size of the ostium in the diseased sinuses when compared to normal sides.

<u>Anterior Ethmoidal artery</u>

Basak et al [26] reported that 43% of the AEA are away from the ethmoidal roof .Floreani et al [43] reported that the anterior ethmoidal artery may lie in a mesentery suspended from the skull base with an incidence of 34%.

In our series, It was included in a roof in 16%, mesentery in 29.50% and away from the roof, freely in the ethmoid in 54.50%

When the artery lies freely in the ethmoid, as was the majority in our series, it is prone to iatrogenic trauma and hence tissue handling should be very meticulous in the frontal recess region.

Suprabullar recess

In case of a suprabullar recess, when the bulla is dehiscent and not attached to skull base, the anterior ethmoidal artery lies freely in the frontal recess and hence prone to trauma during surgeries.

In our series, supra bullar recess was found in 24.50% of the sides.

Keros classification

In a study by Mohammad et al [22] Keros type I was seen in 46 sides (29.80%), type II in 75 sides (48.70%) and type III was seen in 33 (21.40%) sides. Keros type I was seen in 38 sides in males and 8 sides in females. Type II was seen in 46 and 29 sides in males and females, respectively. Type III was seen in 18 sides in males and in 15 sides in females.

In our series,

Type 1 – 19.50%

Type 2 – 79.50%

Type 3 – 1%

As understanding of the anatomy of ethmoid roof along with its possible variation is crucial to give the surgeon optimal information about the possible risk that one can face during the surgery, thereby avoiding dreadful complications, Keros classification comes into play.

Type 3 is considered to be the most prone for iatrogenic trauma, however it is rare as seen in our series. Nevertheless type 2 keros is second in line and constitutes the majority pattern.

Asymmetry of ethmoidal roof

Floreani et al [43], found that the right fovea ethmoidalis was higher than the left in 59% of patients.

In a study by Richard et al [21] in a retrospective review of coronal CT scans, 9.5% of them had an asymmetry between the height of the fovea ethmoidalis on the right and left sides. Of these, 63.20% were lower on the rightside, whereas 36.80% were lower on the left.

In our study, asymmetry was noted in 80% of the sides and majority (58%) of the sides were lower on the right side and 22% were lower on the left side. (Fig.21 & Fig.22)

While operating, asymmetry of the skull base has to be kept in mind and the surgeon has to be careful while operating on the side with the lower level to avoid injury to the skull base.

Topography of the skull base

In our study, we found that the sphenoid was lower in 129 sides (64.50%) and posterior ethmoid was lower in 71 sides (34.50%)

CONCLUSION

In this study, we could outline the various patterns of pneumatization in the frontal recess in our patients using 3- Dimensional Computerised Tomography.

We did not find a significant relation for any particular frontal recess cell or pneumatisation pattern for being the sole cause for chronic frontal sinusitis. Therefore we conclude that the pneumatisation pattern in combination with various other factors, especially mucosal oedema, contributed to the etiopathogenesis of chronic frontal sinusitis.

The anterior ethmoidal artery was found to run freely in the ethmoids, away from the skull base in most of the patients.

BIBLIOGRAPHY

1. Bolger WE, Mawn CB (2001). Analysis of the suprabullar and retrobullar recesses for endoscopic sinus surgery. Ann Oto Rhinol Laryngol; 110 : 3–14

2. Yun, In Sik, Kim, Yong Oock et al. Three-Dimensional Computed Tomographic Analysis of Frontal Sinus in Asians; Journal of Craniofacial Surgery: March 2011, Vol. 22, Issue 2; 462-467.

3. Fernando et al; Analysis of the Agger nasi cell and frontal sinus ostium sizes using computed tomography of the paranasal sinuses. Braz J Otorhinolaryngol. 2013; 79(3):285-92.

4. Roee Landsberg, MD; Michael Friedman, MD; A Computer-Assisted Anatomical Study of the Nasofrontal Region Laryngoscope; 111:2125–2130, 2001.

5. Bent JP, Cuilty-Siller C, Kuhn FA. The frontal cell as a cause of frontal sinus obstruction. Am J Rhinol 1994;8:185-91.

6. Langille, Morgan; Walters et al ; Frontal sinus cells: Identification, prevalence, and association with frontal sinus mucosal thickening; American Journal of Rhinology & Allergy, Volume 26, Number 3, May/June 2012 , pp. e107-e110.

7. Luo Zhang, MD, Demin Han, MD et al, Computed tomographic and endoscopic analysis of supraorbital ethmoid cells ; Otolaryngology–Head and Neck Surgery (2007) 137, 562-568.

8. Leunig A, Betz CS, Sommer B, Sommer F. Anatomic variations of the sinuses; multiplanar CT-analysis in 641 patients. Laryngorhinootologie.2008 Jul;87(7):482-9. doi: 10.1055/s-2007-995572.

9. Kanowitz, Seth J.et al; Utility of Sagittal Reformatted Computerized Tomographic Images in the Evaluation of the Frontal Sinus Outflow Tract. American Journal of Rhinology, Volume 19, Number 2, March-April 2005 , pp. 159-165(7).

10. Kew J, Rees GL, Close D, et al. Multiplanar reconstructed computed tomography images improves depiction and understanding of the anatomy of the frontal recess. American J Rhinol 2002;16:119-23.

11. Walter T. Lee, Frederick A. Kuhn 3D computed tomographic analysis of frontal recess anatomy in patients without frontal sinusitis; Otolaryngol Head Neck Surg 2004;131:164-73.

12. Heinz Stammberger. Functional Endoscopic sinus surgery

13. Lund VJ, Kennedy DW. Quantification for staging sinusitis, The staging and therapy group ; Ann OtolRhinolLaryngol 1995; 167:17-21

14. James A. Stankiewicz. Advanced Endoscopic sinus surgery

15. Kuhn FA. Chronic frontal sinusitis: the endoscopic frontal recess approach. Op Tech Otolaryngol Head Neck Surg1996;7:222–229.

16. Jacobs et al, 100 years of frontal sinus surgery. Laryngoscope 1997; 107:1

17. Turgut et al. The relationship between frontal sinusitis and localization of frontal sinus outflow tract. Archives of otolaryngology head and neck surgery 2005; 131:518-522.

18. Sedaghat AR, Gray ST, Wilke CO, Caradonna DS. Int Forum Allergy Rhinol. 2012 Sep-Oct;2(5):370-5. doi: 10.1002/alr.21055. Epub 2012 May 30.

19. John M. Del Gaudio, MD; Patricia A. Hudgins, MD; Giri Venkatraman, MD; Alec Beningfield, MD Effect on Frontal Isthmus Size and Frontal Sinusitis Arch Otolaryngol Head Neck Surg. 2005;131:230-235

20. Terrier FW, Ruefenacht W, Porcellini DB. Anatomy of the ethmoid: CT, endoscopic, and macroscopic. Am J Rhinol 1985;144:493–500.

21. Richard A. Lebowitz, MD; Alyssa Terk, BA; Joseph B. Jacobs, MD; Roy A. Holliday, MD Asymmetry of the Ethmoid Roof: Analysis Using Coronal Computed Tomography Laryngoscope, 111:2122–2124, 2001

22. Mohammad Adeel, Mubasher Ikram, Mohammad Shaheryar Ahmed Rajput, AsifArain, Yasir Jamil Khattak. Asymmetry of lateral lamella of the cribriform plate: a software-based analysis of coronal computed tomography and its clinical relevance in endoscopic sinus surgery SurgRadiolAnat DOI 10.1007/s00276-013-1106-4.

23. Ching-Feng Lien et al, Computed Tomographic Analysis of Frontal Recess Anatomy and its Effect on the Development of Frontal Sinusitis; Laryngoscope, 120:2521–2527, 2010

24. Kainz J, Stammberger H. The roof of the anterior ethmoid: a locus minor resistentiae in the skull base. LaryngolRhinolOtol 1988;67:142-9.

25. L.Lannoy-Penisson1, P. Schultz, The anterior ethmoidal artery: radio-anatomical comparison and its application in endonasal surgery Acta Oto-Laryngologica, 2007; 127: 618-622.

26. Basak S, Karaman C-Z, Akdilli A. Evaluation of some important anatomicalvariations and dangerous areas of the paranasal sinuses by CT for safer endonasal surgery. Rhinology 1998;36:162-7.

27. Soraia Ale Souza1, Marcia Maria Ale de Souza, Luís Carlos Gregório, Sergio Ajzen, Anterior Ethmoidal Artery Evaluation on Coronal CT Scans Braz J Otorhinolaryngol 2009;75(1):101-6.

28. Anagha A.Joshi, Kshitij D.Shah, Renuka A.Bradoo Radiological correlation between the anterior ethmoidal artery and the supraorbital ethmoid cell. Indian J Otolaryngol Head Neck Surg (July–September 2010) 62(3) (Rhinology):299–303.

29. Reidel BM: Totale resection der facialen und orbitalensternholenwand. In Denker A, Kahler O (eds): Handbuch der Hals-Nasen-OhrenHeikund, vol 2. Berlin, Springer Verlag, 1926, p806.

30. Weber R, Draf W, Khale G, Kind M. Obliteration of the frontal sinus: State of art and reflection on new materials.Rhinology.1999; 37: 1-15.

31. Lynch RC. The technique of a radical frontal sinus operation which has given me the best results. Laryngoscope.1921; 31:1-5.

32. Ogston A. Trephining the frontal sinuses for catarrhal diseases. Medical Chronicle. 1884/85; 1:235-8.

33. Stammberger H. "Uncapping The Egg"- The Endoscopic Approach to Frontal Recess and Sinuses.Tuttlingen: Endo-Press; 1999.

34. Luc H: Contribution a l'etude des suppurations du sinus frontal et en particulier de son traitement chirurgical. Arch Internat de Laryngl, 1894; 185: 7.

35. Wormald PJ: Endoscopic Sinus Surgery: Anatomy, Three-Dimensional Reconstruction, and Surgical Technique. New York, NY, Thieme, 2005.

36. Finn J, Chapman ME, Wightman AJA, Maran AGD. A prospective analysis of incidental paranasal sinus abnormalities on CT head scans. ClinOtolaryngol Allied Sci 1994;19(4):287-289.

37. Lusk RP, Muntz HR. Endoscopic sinus surgery in children with chronic sinusitis: a pilot study. Laryngoscope 1990;100(6):654-658.

38. Kennedy DW, Zinreich SJ. The functional endoscopic approach to inflammatory sinus disease : current perspectives and technique modifications. Am J Rhinol 1988;2:89-96.

39. Wormald PJ. The aggernasi cell: the key to understanding the anatomy ofthe frontal recess. Otolaryngol Head Neck Surg 2003; 129 (5):497-507.

40. Wormald PJ. The axillary flap approach to the frontal recess. Laryngoscope 2002; 112(3):494-499.

41. Wormald PJ, Chan SZX. Surgical techniques for the removal of frontal recess cells obstructing the frontal ostium. Am J Rhinol 2003;17(4):221-226.

42. Meyer et al. Coronal CT analysis of frontal cells. American Journal of Rhinology, 2003; 17:163-168.

43. Floreani SR, Nair SB, Switajewski MC, Wormald PJ. Endoscopic anterior ethmoidal artery ligation: a cadaver study. Laryngoscope 2006; 116(7): 1263-1267.

44. Mark C loury; Endoscopic frontal recess and frontal sinus ostiumdissection; Laryngoscope 103; April 1993.

45. Kennedy DW, Senior BA: Endoscopic sinus surgery–A review. Otolaryngol Clin North Am 30:313-330, 1997.

46. Thawley SE, Deddens AE: Transfrontal endoscopic management of Frontal recess disease. Am J Rhinol 9:307-311, 1995.

47. Ramadan HH: Surgical causes of failure in endoscopic sinus surgery. Laryngoscope 109:27-29, 1999.

48. Wormald PJ: Surgery of the frontal recess and frontal sinus. Rhinology 43:83-85, 2005.

49. John P.Bent, Carlos Cuilty-Siller, and Frederick A.Kuhn. The Frontal Cell as a Cause of Frontal Sinus obstruction .American Journal Rhinology.1994; 8:185-191.

50. Friedman M, Landsberg R: Frontal sinus surgery: Endoscopic technique.Op Tech Otolaryngol Head Neck Surg 12:60-65, 2001.

51. Owen RG, Kuhn FA: The maxillary sinus ostium: Demystifying middle Meatus antrostomy. Am J Rhinol 9:313, 1995.

52. Friedman M, Landsberg R, Tanyeri H: Intraoperative and postoperative assessment of frontal sinus patency by transillumination. Laryngoscope 110:683-684, 2000.

53. Friedman M, Landsberg R, Tahyeri H: Middle turbinate medialization andpreservation in endoscopic sinus surgery. Otolaryngol Head Neck Surg 123:76-80, 2000.

54. Swanson PB, Lanza DC, Vinning EM, et al: The effect of middle turbinate resection upon the frontal sinus. Am J Rhinol 9:191-195,1995.

55. Van Alyea. Frontal cells : an anatomic study of these cells with consideration of their clinical significance. Archives of Otolaryngology Head and Neck Surgery 1941; 34:11

56. Benjamin et al ; Failed Endoscopic Sinus Surgery: Spectrum of CT Findings in the Frontal Recess, RadioGraphics 2009; 29:177–195

57. Endoscopic surgery of the Paranasal sinuses and anterior skull base; Malte Erik Wigand; 2nd edition; Thieme; 2008

58. Endoscopic localization of the anterior and posterior ethmoid arteries.Han JK, Becker SS, Bomeli SR, Gross CW. Ann OtolRhinolLaryngol. 2008 Dec;117(12):931-5.

59. Schaeffer J. The genesis, development and adult anatomy of the nasofrontal duct region in man. Am J Anat 1916; 20:125-14

60. Kasper K. Nasofrontal connections: a study based on one hundred consecutive dissections. Arch otolaryngol 1936:24:322-343

61. Shah RK, Dhingra JK, Carter BL et al. Paranasal sinus development : a radiographic study. Laryngoscope 2003; 113(2):205-209

62. Lanza DC. Diagnosis of chronic rhinosinusitis. Ann Otol Rhinol Laryngol Suppl 2004;193:10-14

‘FRONTAL RECESS ANATOMY’

RADIOLOGICAL STUDY AND ITS’ SURGICAL IMPLICATIONS

PROFORMA – CASES

Serial no:

Name : Age: Sex: Hospital No:

Address:

Clinical Symptoms & Signs

0-no symptom/sign/normal, 1- mild, 2-moderate, 3-severe

A-present, B-Absent

SYMPTOMS		
MAJOR CRITERIA	RIGHT	LEFT
Facial congestion/fullness		
Nasal Discharge		
Nasal Obstruction		
Facial pressure/pain		
Postnasal drip		
Impaired smell		
MINOR CRITERIA		
Headache		
Fever		

Halitosis		
Cough		
Dental pain		
Fatigue		
Otalgia/aural fullness		
SIGNS		
DNS		
Inferior Turbinate Hypertrophy		
Middle turbinate		
Nasal discharge		
Nasal mucosa		
Post Nasal Discharge		

History of : (If yes, Specify) Nasal allergies -

Oral/nasal drug intake –

Systemic disease –

CT SCAN - PNS (3-D RECONSTRUCTION)

	RIGHT	LEFT
Frontal sinus (0-normal, 1-hypoplastic, 2-hyperplastic)		
Frontal Recess (0- normal, 1- obstructed)		
Frontal sinus disease (LM Grading 0,1,2)		
AggerNasi Cell (0-absent, 1- present)		
Bulla Ethmoidalis superior attachment (0-Dehiscent, 1-Attached)		
Frontal cells (1-type 1, 2-type 2, 3-type 3, 4-type 4)		
Frontal bullar cell (0-absent, 1-present)		
Suparabullar cell (0-absent, 1-present)		
Suprabullar recess/sinus lateralis (0-absent, 1-present)		
Supraorbital ethmoidal cell (0-absent, 1-present)		
Interfrontal sinus septal cell (0-absent, 1-present)		
Uncinate attachment (types 1,2,3,4,5,6)		
Anteroposterior diameter of nasofrontal isthmus in mm (transverse)		
Area of nasofrontal isthmus (mm^2)		
Anterior ethmoidal artery (grade 1,2,3)		
Fovea Ethmoidalis		
Olfactory fossa (Keros Type 1/2/3)		
Topography - lowest level of skull base (1-sphenoid,2- posterior ethmoid)		

‘FRONTAL RECESS ANATOMY’

RADIOLOGICAL STUDY AND ITS’ SURGICAL IMPLICATIONS

PROFORMA – CONTROL GROUP

Serial no:

Name : Age: Sex: Hospital No:

Address:

Chart review

Presenting symptoms:

Clinical diagnosis:

Other systemic diseases:

CT SCAN - PNS (3-D RECONSTRUCTION)

	RIGHT	**LEFT**
Frontal sinus (0-normal, 1-hypoplastic, 2-hyperplastic)		
Frontal Recess (0- normal, 1- obstructed)		
Frontal sinus disease (LM Grading 0,1,2)		
AggerNasi Cell (0-absent, 1- present)		
Bulla Ethmoidalis superior attachment (0-Dehiscent, 1-Attached)		
Frontal cells (1-type 1, 2-type 2, 3-type 3, 4-type 4)		
Frontal bullar cell (0-absent, 1-present)		
Suparabullar cell (0-absent, 1-present)		
Suprabullar recess/sinus lateralis (0-absent, 1-present)		
Supraorbital ethmoidal cell (0-absent, 1-present)		
Interfrontal sinus septal cell (0-absent, 1-present)		
Uncinate attachment (types 1,2,3,4,5,6)		
Anteroposterior diameter of nasofrontal isthmus in mm & (transverse)		
Area of nasofrontal isthmus (mm^2)		
Anterior ethmoidal artery (grade 1,2,3)		
Fovea Ethmoidalis		
Olfactory fossa (Keros Type 1/2/3)		
Topography - lowest level of skull base (1-sphenoid,2- ethmoid)		

‘Frontal recess anatomy – Radiological study & its’ surgical implications’

Patient information sheet

Dear sir/madam, you have been clinically diagnosed to have infection of the frontal sinus

(Chronic frontal sinusitis) which has not responded to medical line of management, therefore it requires you to undergo a special X- Ray examination called a CT scan or computerised tomography of the paranasal sinuses for further evaluation and management. During this test, a thin X ray beam is rotated around the area of the body the doctor wants more information about. The computer collects the data and uses it to make a very detailed 3-D picture which can help the doctors diagnose problems and plan treatment.

The scan itself is painless, but you will have to remain completely still on the examination table while the scan is being done. In some cases, a special dye is needed to help the organs show up more clearly. If this is necessary, your doctor will tell you. You are also included in an observational study, which will help us in accurately diagnosing and planning better treatment for you and for others suffering from similar disease.

RISKS

Apart from the common risk mentioned, there may be other unusual risks that have not been listed here. Please ask your doctor if you have any general or specific concerns.People are exposed to radiation from natural sources all the time. All X-Rays involve a small extra dose of radiation. The dose of radiation used for CT examinations is carefully controlled to ensure the smallest possible amount is used that will still give a useful result.

However, all radiation exposure is linked with a slightly higher risk of developing cancer. The size of any increased risk depends on the age of the patient and the total amount of radiation received. The risk of any one scan is very small indeed, but increases if many scans are needed. The doctor(s) asking for this test will have weighed any risk against the benefit to be gained from the extra information the CT scan should provide.There may be risks associated with the use of X-ray dye such as allergic reactions.

As a CT scan is usually avoided if a woman is pregnant, you should ask the doctor if this may affect you .

If you suffer from claustrophobia, you may find it difficult to remain still within the scanner and should warn the staff beforehand .

CONSENT FORM

DECLARATION BY PATIENT

I acknowledge the doctor has informed me about the procedure, other options and answered my specific queries and concerns about this matter.

I acknowledge that I have discussed with the doctor any significant risks and complications specific to my personal circumstances that I have considered in deciding to have this scan.

Signature of patient / guardian Date

Name -

Relationship to patient –

DECLARATION BY DOCTOR

I declare that I have explained the nature and consequences of the scan to be performed, and discussed the risks that particularly concern the patient or the /guardian(s). I have given the patient and the guardian(s) an opportunity to ask questions and I have answered these.

Doctor's signature Date

Doctor's name -

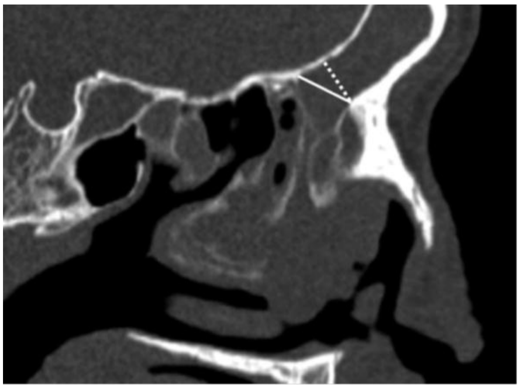


Figure 01: A-P length of the frontal isthmus (FI; dotted line) and frontal recess (FR; solid line)

This is an image showing a parasagittal cut at the level of the frontal recess. The anterior to posterior (A-P) length of the frontal isthmus is the shortest length between the most prominent point of the frontal beak and the point of the posterior wall of the frontal sinus. The A-P length of the FR is the length between the most prominent point of the frontal beak and the superior attachment of ethmoid bulla lamella to the skull base.

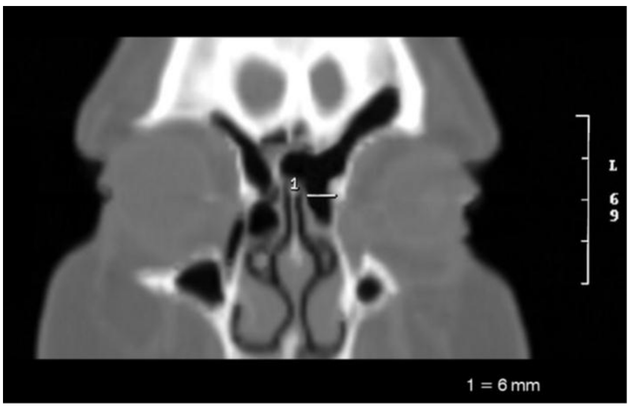


Figure 02 : Side-to-side measure of the frontal sinus ostium [3]

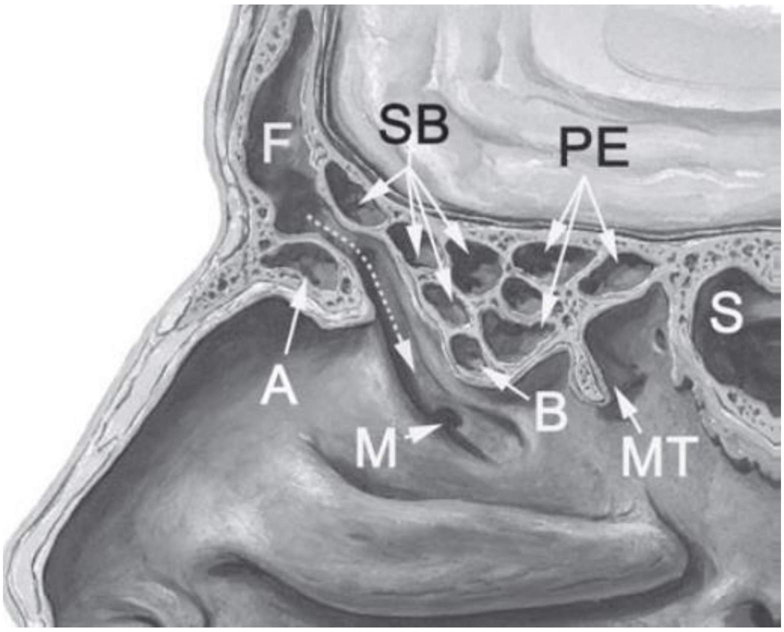
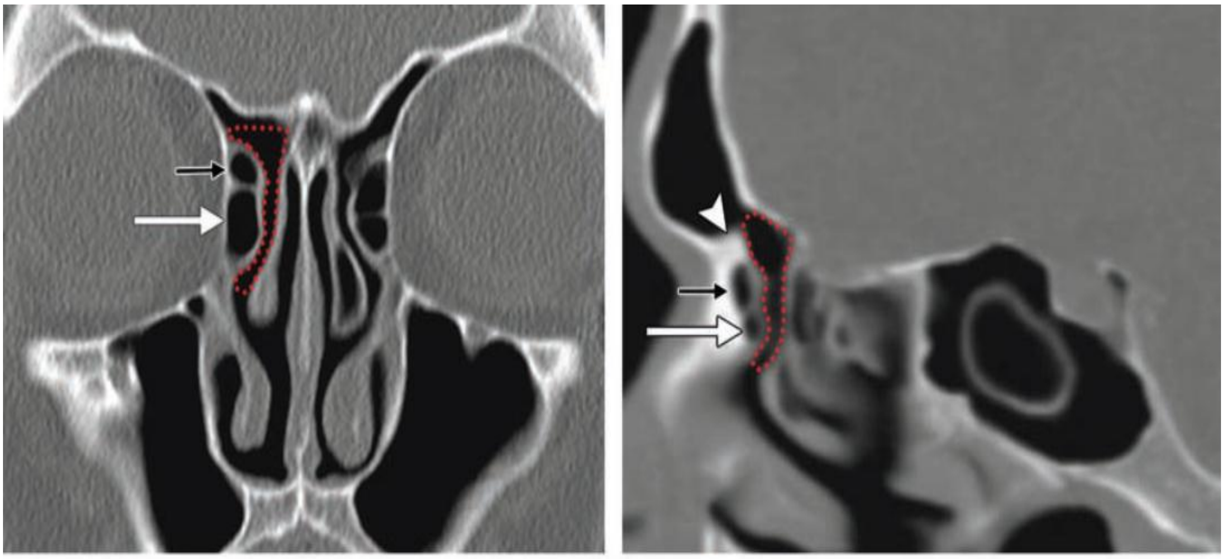


Figure 03 : Parasagittal view of a right frontal recess

The agger nasi (A) and suprabullar (SB) cells are, respectively, the anterior and posterior boundaries of the frontal recess (dotted arrow).The anterior portion of the middle turbinate (not seen in figure), represents its medial limit. The frontal sinus (F), the ethmoid bulla (B), the posterior ethmoid cells (PE), their relation to the tail of the middle turbinate (MT), the sphenoid sinus (S) and the natural ostium of the maxillary sinus (M) is seen.



a. b.

Figure 04 : Normal frontal recess anatomy [19]

Coronal (a) and sagittal (b) CT images showing the right frontal recess (dotted red line), which is bounded anteriorly and laterally by an agger nasi cell (white arrow) and a type 1 frontal cell (black arrow), medially by the middle turbinate, and posteriorly by the bulla ethmoidalis and bulla lamella. The nasofrontal process (arrowhead in b) forms the floor of the frontal sinus and marks the level of the frontal sinus ostium.

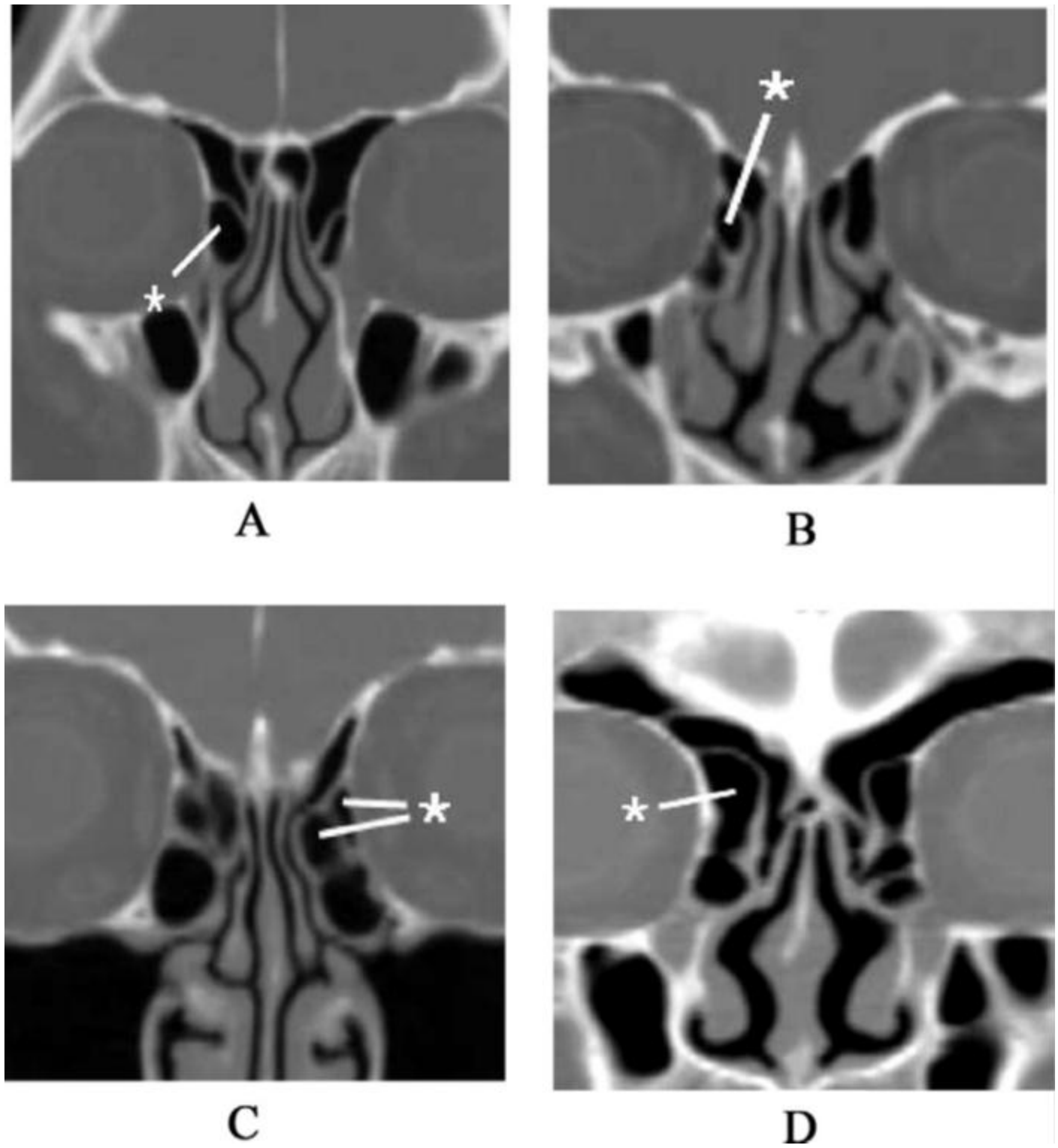


Figure 05 : Coronal CT images (A) Agger nasi cell (*); (B) FC1 (*); (C) FC2 (*); (D) FC3 (*)

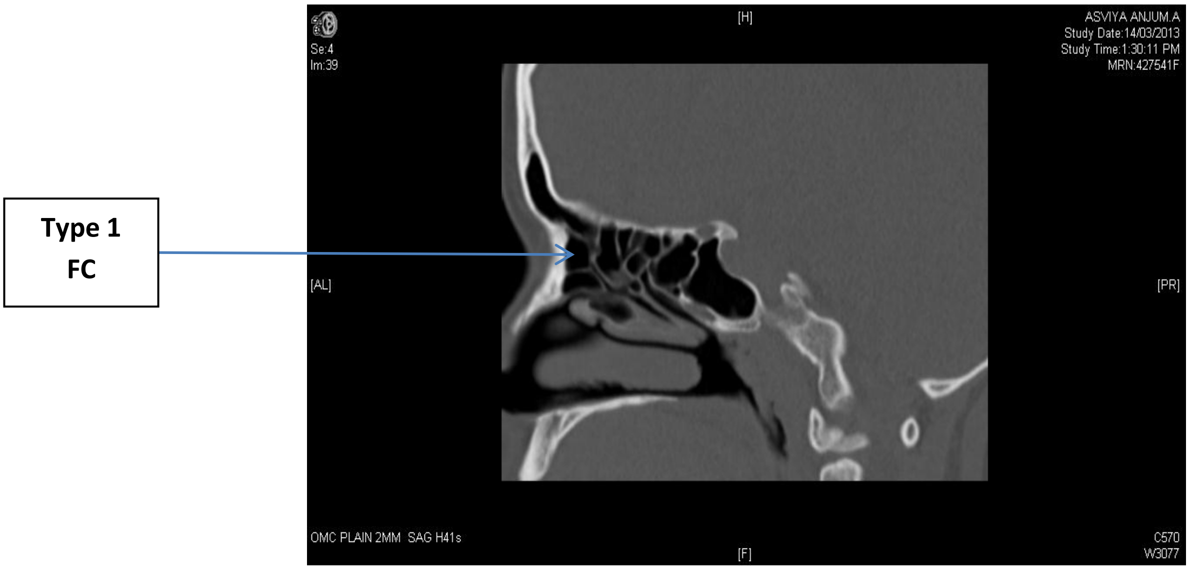


Figure 06 : Sagittal cut showing type 1 frontal cell.

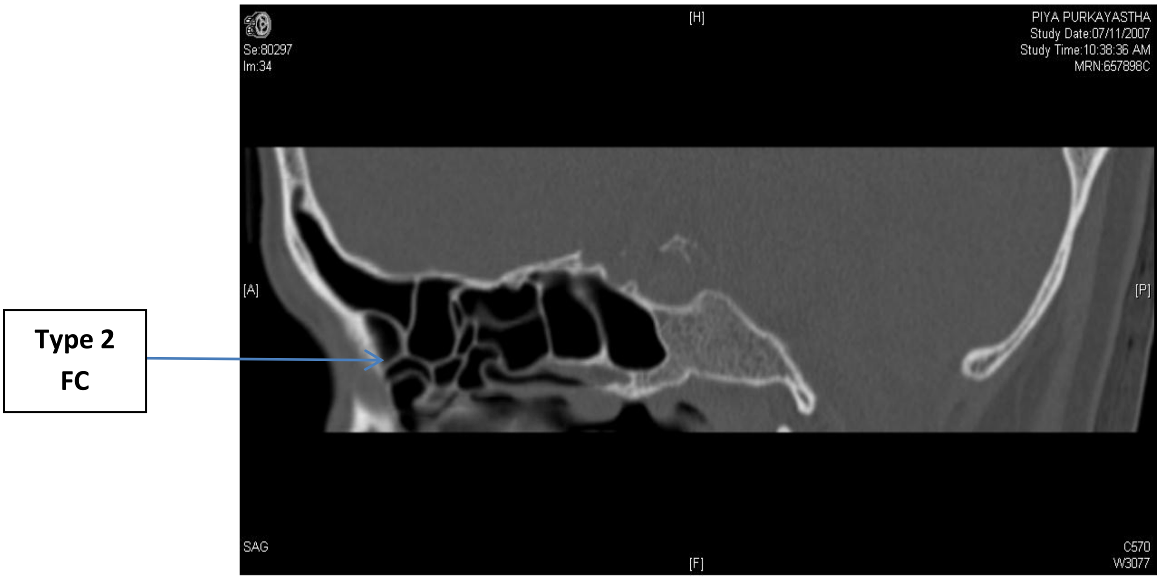


Figure 07 : Sagittal cut showing type 2 frontal cell.

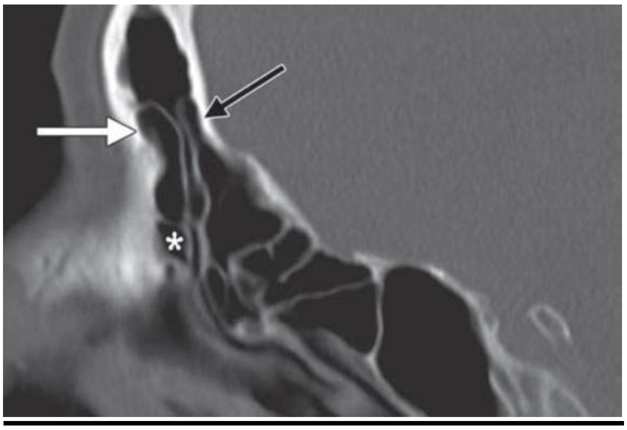


Figure 08 : Type 3 frontal cell and frontal bullar cell [56]

Sagittal CT image obtained through the frontal recess shows a type 3 frontal cell (white arrow) sitting above an agger nasi cell (*) and extending superiorly into the frontal sinus. Also note the frontal bullar cell (black arrow), which pneumatises along the skull base from the posterior frontal recess into the frontal sinus.

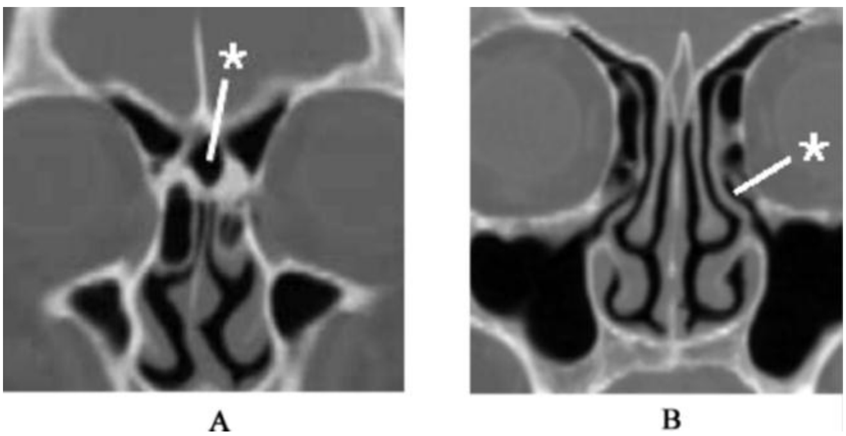


Figure 09 : (A) IFSSC (*) is seen on coronal CT; (B) RT (*) is seen on coronal sinus CT.

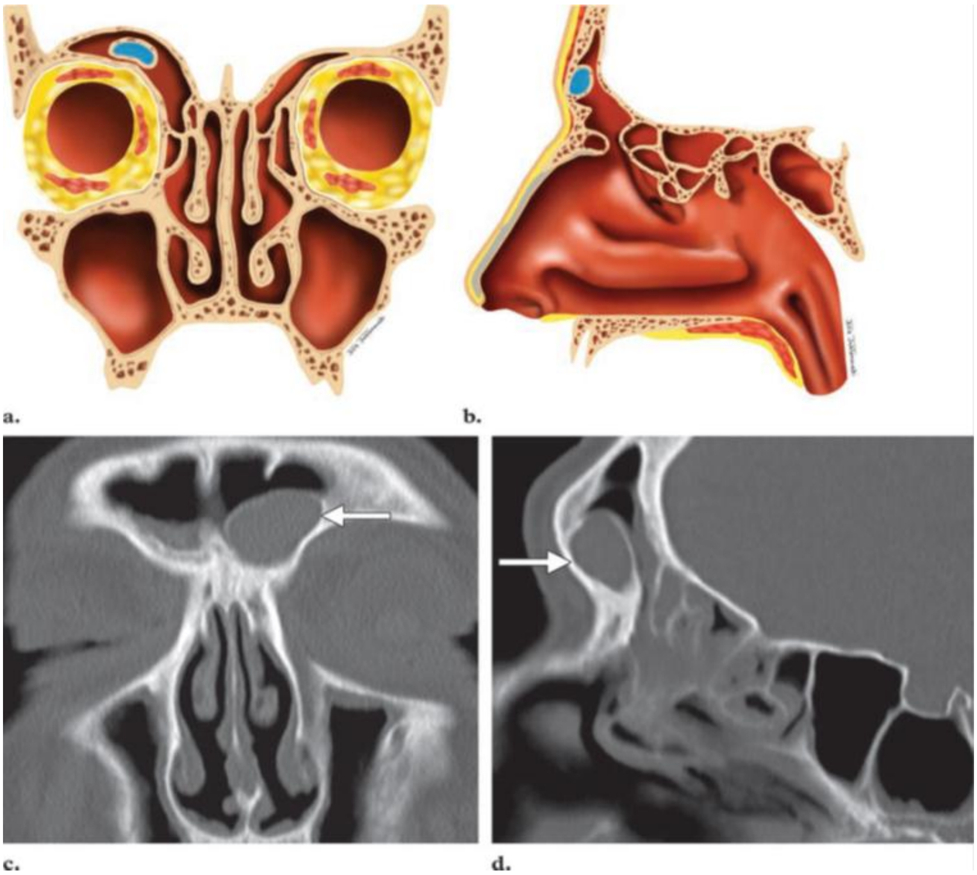


Figure 10 : Type 4 frontal cell [56]

Coronal (a) and parasagittal (b) drawings show a type 4 frontal cell (blue area) situated entirely within the right frontal sinus and bordered by the anterior frontal sinus wall. The type 4 cell does not abut the agger nasi cell. (c,d)

Coronal (c) and sagittal (d) CT images show an opacified type 4 frontal cell (arrow) in the frontal sinus.

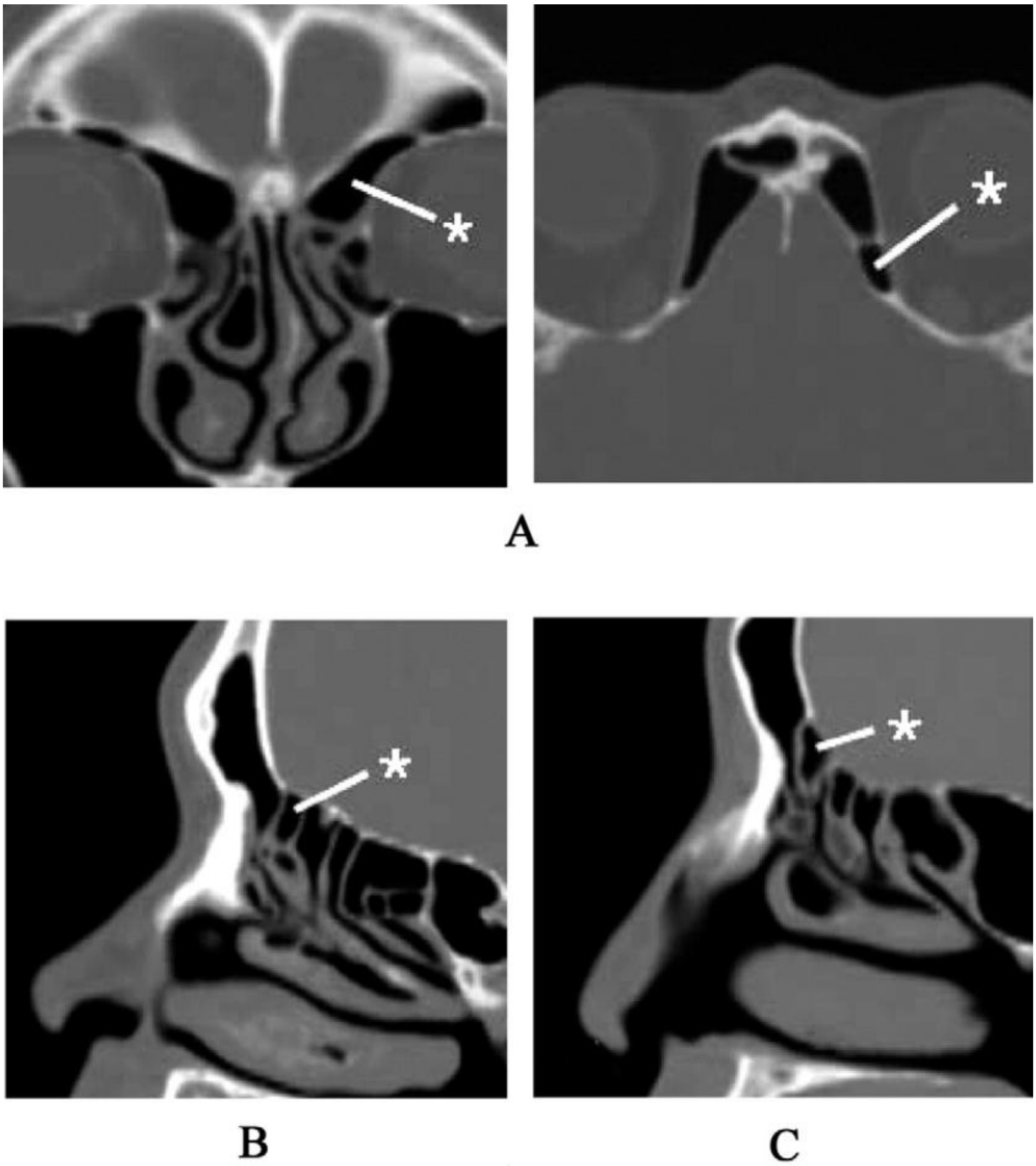


Figure 11 : (A) SOEC (*) is seen on axial and coronal CT images. (B) SBC (*) is seen on sagittal CT; (C) FBC (*) is seen on sagittal CT.

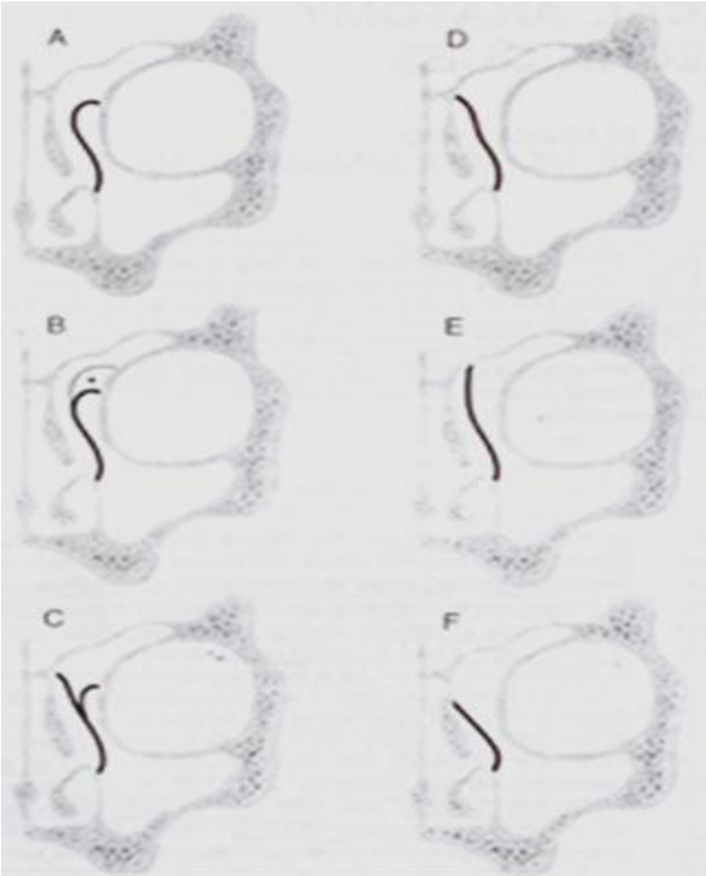


Figure 12 : Superior attachment of uncinate process - Types 1-6 (A-F)

Type 1 : insertion into lamina papyracea

Type 2 : insertion into posteromedial wall of agger nasi cell

Type 3 : insertion into both LP and the junction of MT with cribriform plate

Type 4 : insertion into junction of MT with cribriform plate

Type 5 : insertion into skull base

Type 6 : insertion into middle turbinate

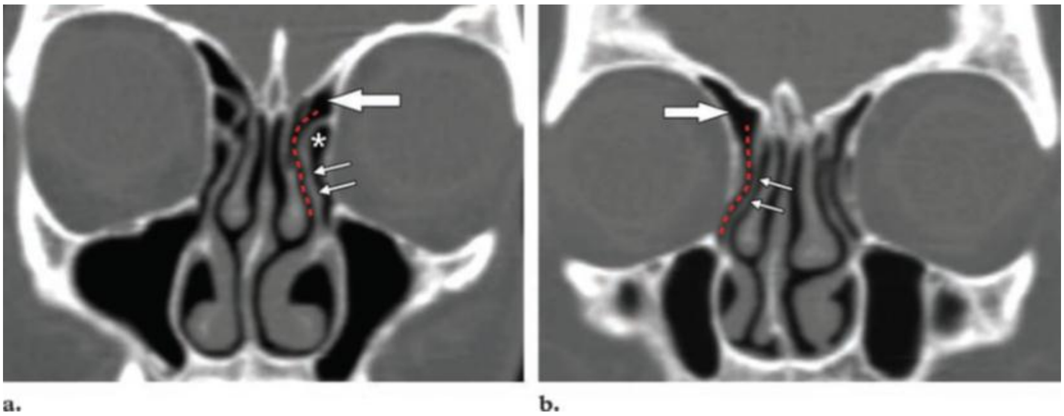


Figure 13: Effect of the superior attachment of the uncinate process on frontal recess drainage. [56]

Fig (a) Large arrow - superior aspect of the frontal recess. UP attached to the lamina papyracea. As a result, the ethmoid infundibulum terminates in a blind recess known as the recessus terminalis (*). In this case, frontal recess drainage (dashed red line) passes directly into the middle meatus.

Fig (b) Coronal CT image from another patient shows the uncinate process (small arrows) attached to the skull base at the junction of the cribriform plate and lateral lamella. Therefore, frontal recess drainage (dashed red line) is directed into the ethmoid infundibulum.

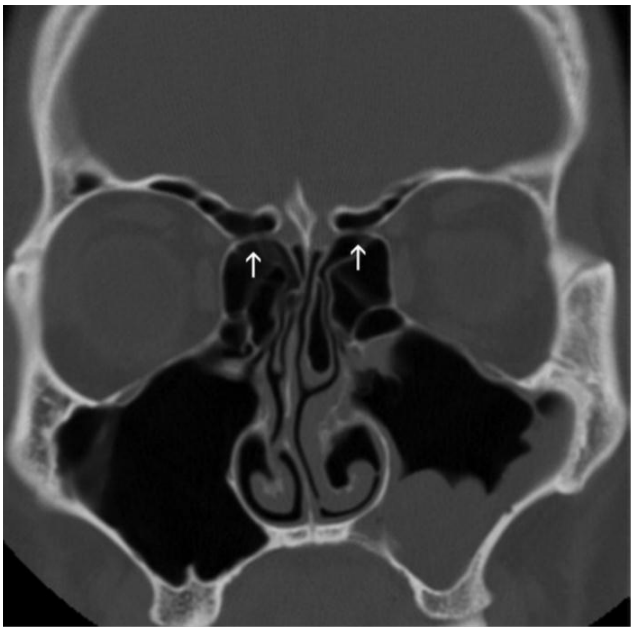


Figure 14 : Anterior ethmoidal canal in its course through the anterior ethmoidal cells (arrows).

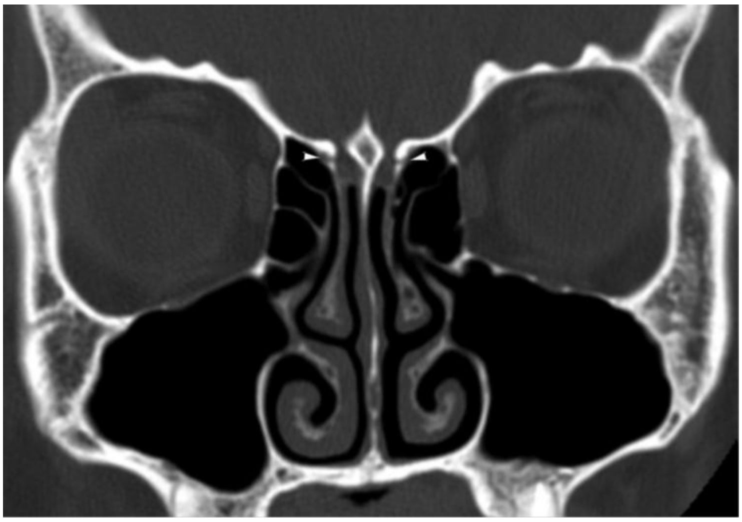


Figure 15: Anterior ethmoidal sulcus - bony sulcus (tip of arrows) on the lateral walls of the olfactory fossae, corresponding to the anterior ethmoidal sulci.

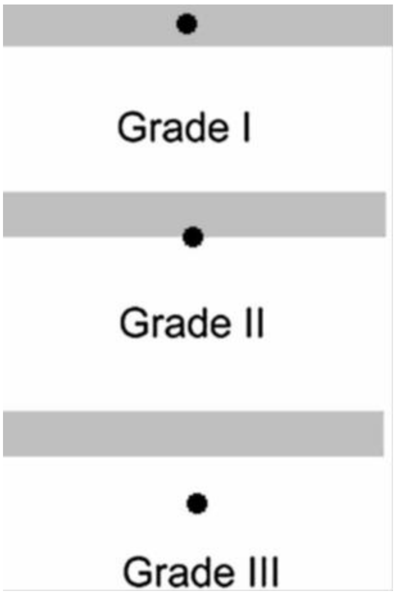


Figure 16: Schematic representation of grades of anterior ethmoidal artery with respect to skull base (grey).

Grade I - Artery included in the roof

Grade II - Artery running under the roof and considered as prominent

Grade III - Artery distant from the ethmoidal roof

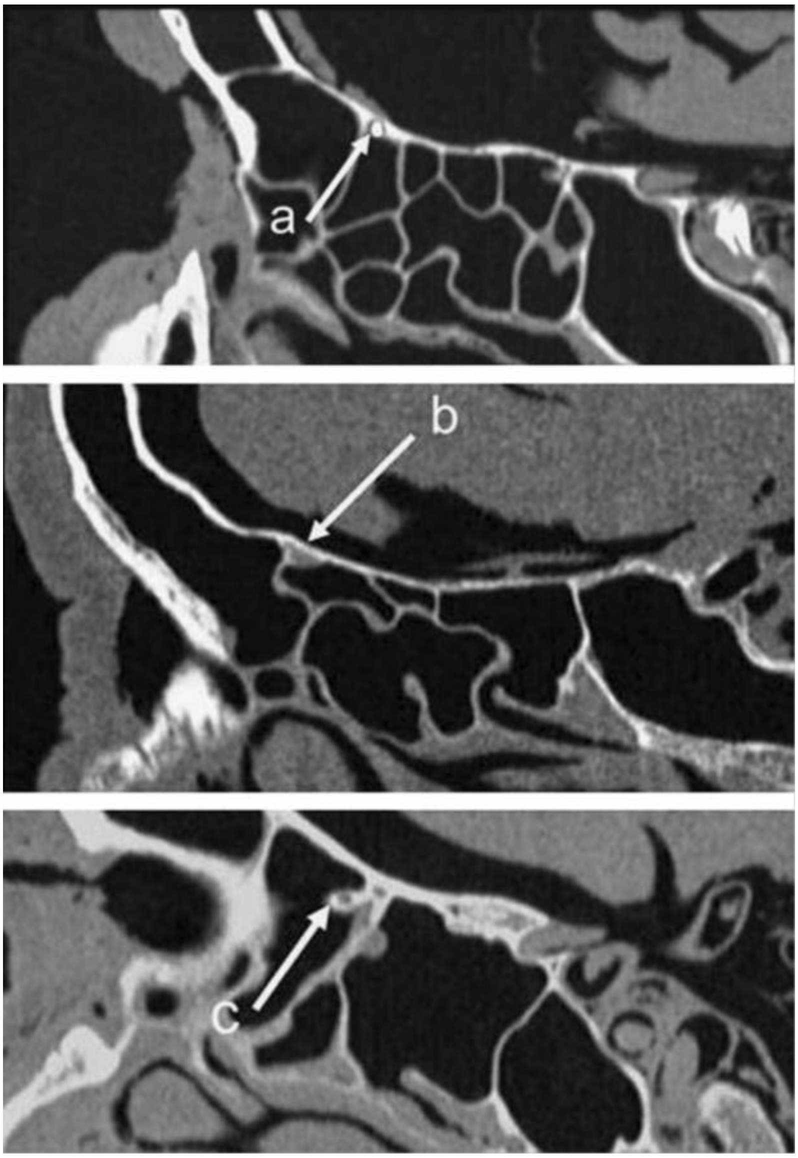


Figure 17 : Sagittal plane showing location of the AEA.

(a) Within the ethmoidal roof

(b) Prominent

(c) Distant from the roof

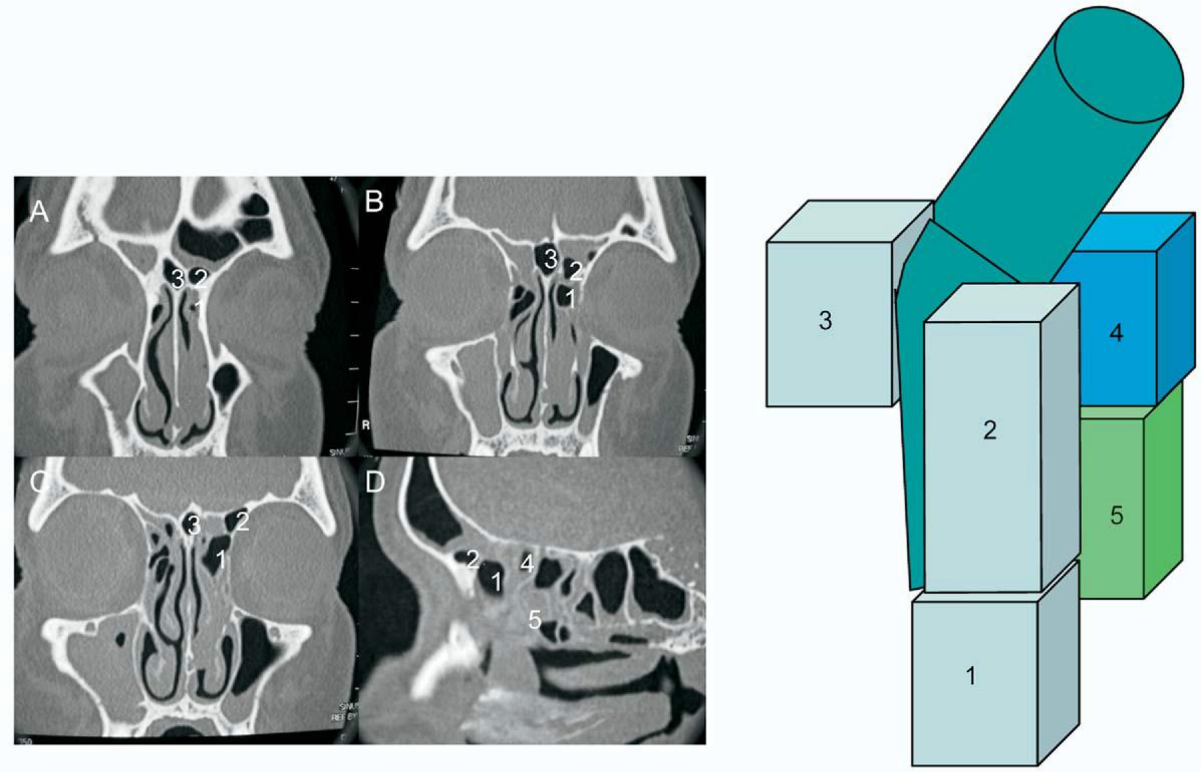


Figure 18 : A building block is placed for each cell numbered on the coronal and parasagittal scans. [35]

This process creates a 3-D picture of the anatomy of the frontal recess, making a complete picture of the cellular anatomy of the frontal recess and frontal sinus. The next step is to determine how the frontal sinus drains in relation to these cells.

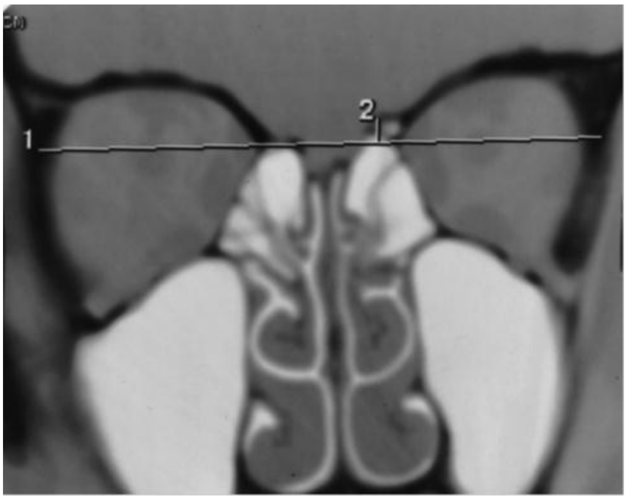


Figure 19 : Coronal CT scan demonstrates a 2 mm height differential between the right (lower) and left fovea.

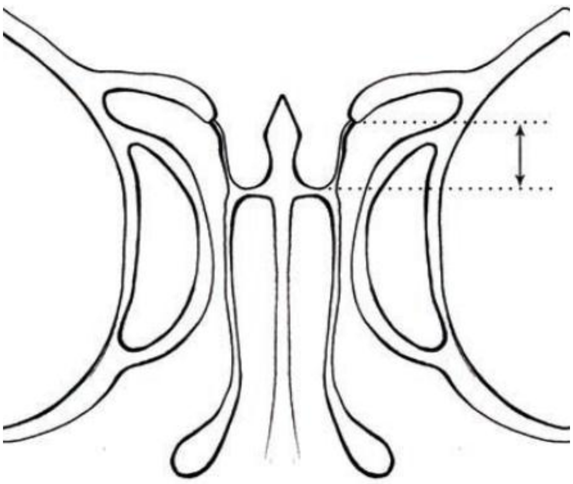


Figure 20 : Coronal view of the olfactory cleft and fossae, in a plane transecting the ethmoid bullae. The arrow measures the length of the lateral lamella of the cribriform plate.

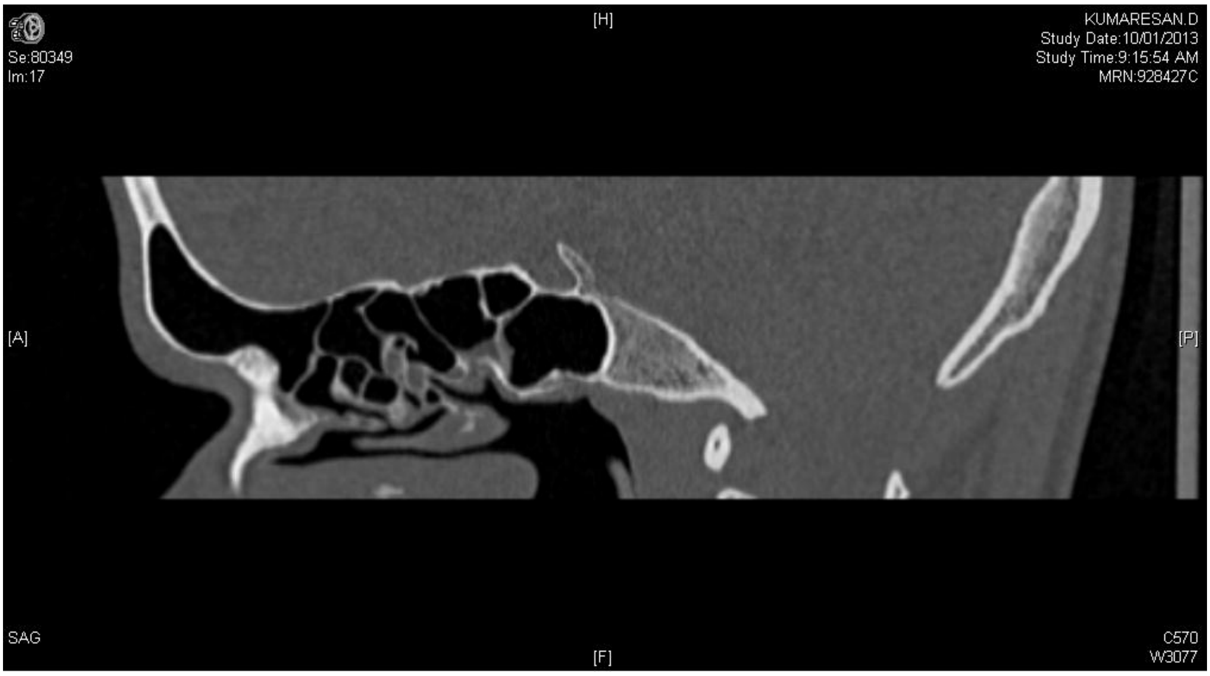


Figure 21 : Sagittal cut showing sphenoid lower than posterior ethmoid

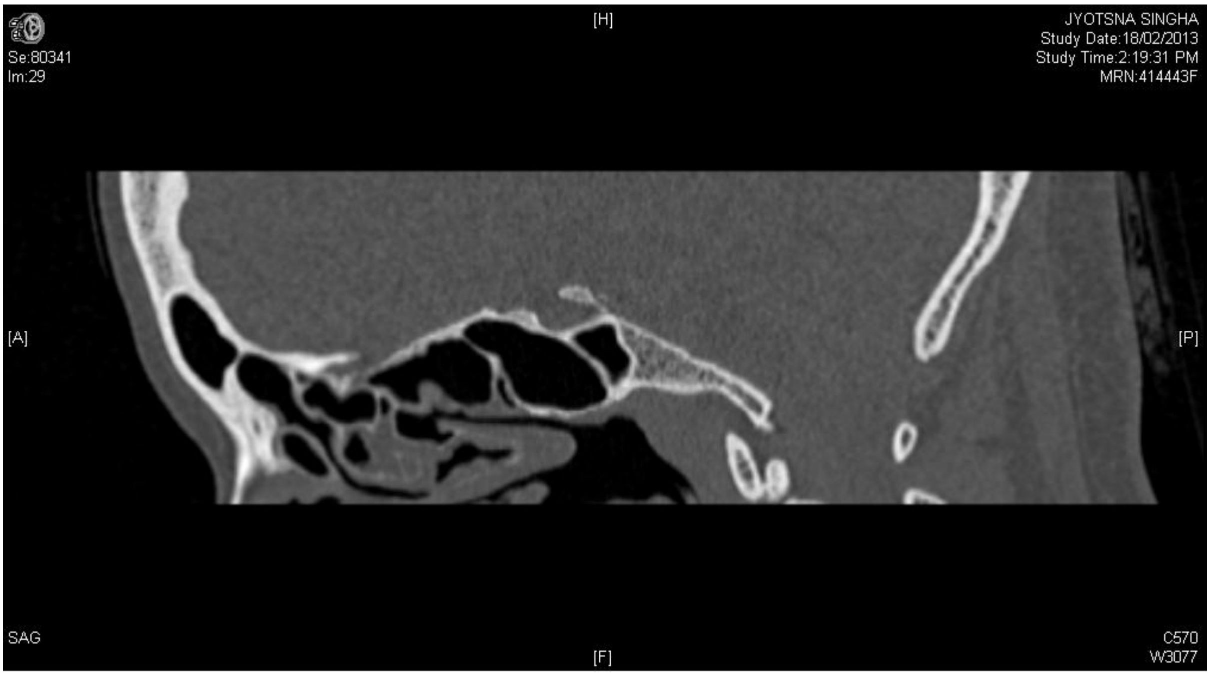


Figure 22 : Sagittal cut showing posterior ethmoid lower than sphenoid

MASTER CHART

ID	age	sex	FS right	FS left	FR right	FR left	FSD right	FSD left	ANC right	ANC left	BES right	BES left	FC right	FC left	FBC right	FBC left	SBC right	SBC left	SBR right	SBR left	SOEC right
A01	38	1	0	0	1	1	1	1	1	1	0	0	3	4	0	0	1	1	0	0	1
A02	24	1	0	0	1	0	2	0	1	1	1	1	0	3	0	0	1	1	0	0	1
A03	52	1	0	0	0	1	0	1	1	1	1	1	3	0	0	0	0	0	0	0	0
A04	31	1	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	1	0	0	1
A05	24	2	0	0	0	0	0	1	1	1	1	0	1	1	0	0	0	1	0	0	0
A06	48	1	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	1	1	0	1
A07	50	2	0	0	0	0	1	1	1	1	0	0	1	1	0	0	1	0	1	1	1
A08	43	1	0	0	0	1	1	1	1	1	0	1	0	1	0	0	1	0	0	0	1
A09	40	2	0	0	0	0	1	0	1	1	1	1	1	3	0	0	1	0	0	0	1
A10	26	2	0	0	0	0	1	0	1	1	0	1	1	1	0	0	1	0	0	0	0
A11	46	1	0	0	0	1	1	1	1	1	1	1	1	3	0	1	0	0	0	0	1
A12	36	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1
A13	29	1	0	0	1	0	1	0	1	1	0	1	0	1	0	0	1	0	0	0	0
A14	46	1	0	2	1	0	1	1	1	1	1	0	0	1	0	0	0	1	0	0	0
A15	29	1	0	0	1	1	2	2	1	0	1	0	1	1	0	0	0	0	0	1	0
A16	32	1	2	2	1	0	2	1	1	1	0	1	3	4	0	0	1	0	1	0	1
A17	34	2	0	2	0	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0
A18	27	2	0	0	1	1	1	2	1	1	1	0	3	2	0	1	0	0	0	0	0
A19	39	2	0	0	0	0	1	1	1	1	0	1	3	1	0	0	1	0	1	0	0
A20	58	1	0	0	0	1	0	1	1	0	0	0	1	0	0	0	1	1	0	0	0
A21	30	1	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
A22	57	1	0	0	1	0	1	1	1	1	1	0	0	1	0	0	0	1	0	0	0
A23	46	1	0	0	0	1	1	1	1	1	0	0	0	1	1	0	0	1	1	1	1
A24	38	1	0	0	0	1	1	1	1	1	0	0	0	0	1	0	1	1	0	1	0
A25	42	2	0	0	0	0	1	1	0	1	1	0	0	0	1	0	0	1	0	0	0
A26	68	1	0	0	0	0	0	1	1	1	1	0	1	3	0	0	0	1	0	0	0
A27	53	1	0	0	0	1	0	1	1	1	0	0	1	1	0	0	1	1	0	0	0
A28	38	2	0	0	1	0	1	0	1	1	1	0	0	1	0	0	0	1	0	0	0
A29	40	1	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0
A30	42	1	0	0	1	1	1	1	0	0	0	1	1	0	0	0	1	0	1	0	0
A31	20	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	1	0	0	0	0
A32	24	1	0	0	1	0	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0
A33	43	1	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0	1	0
A34	50	2	0	0	1	0	2	1	0	1	0	1	0	0	0	0	0	0	0	0	0

ID	age	sex	FS right	FS left	FR right	FR left	FSD right	FSD left	ANC right	ANC left	BES right	BES left	FC right	FC left	FBC right	FBC left	SBC right	SBC left	SBR right	SBR left	SOEC right
A35	33	2	0	0	0	0	0	1	1	1	1	1	3	1	0	0	0	0	0	0	0
A36	76	1	0	0	0	0	0	1	1	1	0	0	1	1	0	0	1	0	0	1	0
A37	38	2	0	0	1	1	1	1	1	0	1	1	1	0	0	0	0	1	0	0	0
A38	28	2	0	0	0	1	1	2	1	0	1	0	0	0	0	1	0	0	0	0	0
A39	45	1	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0
A40	49	1	0	0	0	0	1	0	1	1	1	1	0	1	0	0	1	0	0	0	1
A41	53	2	0	0	0	0	1	1	1	1	1	0	3	1	0	0	0	1	0	1	0
A42	43	1	0	0	1	0	1	0	1	1	1	1	0	1	0	0	0	0	0	0	1
A43	48	1	0	0	0	0	1	1	1	1	1	0	1	1	0	0	0	1	0	0	0
A44	36	1	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0
A45	31	1	0	0	0	0	0	1	1	1	1	0	1	0	0	0	0	1	0	0	1
A46	19	1	2	2	0	0	1	1	1	1	0	0	0	3	0	0	1	1	0	1	1
A47	33	1	1	0	0	0	0	1	1	1	0	0	3	0	0	0	0	1	0	0	0
A48	39	2	0	0	0	0	1	0	1	1	0	1	1	0	0	0	1	0	0	0	0
A49	35	2	0	0	0	0	0	1	1	1	1	0	3	0	0	1	1	1	1	0	0
A50	45	1	0	0	0	0	1	1	1	1	0	0	1	1	0	0	1	1	0	0	1
B01	25	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1	1	0	0	0
B02	37	1	0	0	0	0	0	0	1	1	0	0	2	2	0	0	1	1	1	0	1
B03	47	2	0	0	0	0	0	0	1	1	0	0	3	2	0	0	1	1	1	1	1
B04	47	1	0	0	0	0	0	0	1	1	1	1	0	2	0	0	1	0	0	0	0
B05	52	2	0	0	0	0	0	0	1	1	0	0	1	3	0	0	1	1	1	1	0
B06	28	2	1	0	0	0	0	0	1	1	0	1	3	2	0	1	1	0	1	0	0
B07	26	1	0	0	0	0	0	0	1	1	1	0	3	2	0	0	0	1	0	1	0
B08	38	2	0	1	0	0	0	0	1	1	0	0	1	0	0	0	1	1	1	1	0
B09	50	2	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1	1	1	1	0
B10	34	2	0	0	0	0	0	0	1	1	1	1	0	1	0	0	0	1	0	0	0
B11	29	1	0	0	0	0	0	0	1	1	1	0	3	2	0	0	1	1	0	1	0
B12	21	1	2	2	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	1
B13	22	1	0	0	0	0	0	0	1	1	0	1	3	3	0	0	1	1	1	0	0
B14	52	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	1
B15	40	2	0	0	0	0	0	0	1	1	0	1	1	2	0	0	1	0	1	0	0
B16	57	2	0	0	0	0	0	0	1	1	1	1	1	3	0	0	0	0	0	0	1
B17	32	1	0	0	0	0	0	0	0	1	1	0	3	0	0	0	1	1	0	1	0
B18	30	1	0	0	0	0	0	0	0	1	0	0	3	3	0	0	1	1	1	1	0
B19	35	2	0	0	0	0	0	0	1	1	0	0	2	1	0	1	1	1	1	1	1

ID	age	sex	FS right	FS left	FR right	FR left	FSD right	FSD left	ANC right	ANC left	BES right	BES left	FC right	FC left	FBC right	FBC left	SBC right	SBC left	SBR right	SBR left	SOEC right
B20	60	1	0	0	0	0	0	0	1	1	0	1	2	1	0	0	1	1	1	0	0
B21	42	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	0	0
B22	23	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	0
B23	39	2	0	0	0	0	0	0	1	1	0	0	1	3	0	0	1	1	1	1	0
B24	35	2	1	0	0	0	0	0	1	1	1	1	1	2	1	0	1	1	0	0	0
B25	44	1	0	0	0	0	0	0	1	1	0	0	2	1	0	0	1	1	1	1	1
B26	54	2	0	0	0	0	0	0	1	1	1	1	0	1	0	0	0	0	0	0	0
B27	57	1	0	0	0	0	0	0	1	1	0	0	1	1	0	0	1	1	1	1	1
B28	55	2	0	0	0	0	0	0	1	1	1	0	2	0	0	0	0	1	0	1	1
B29	24	2	0	0	0	0	0	0	1	1	1	0	1	1	0	0	1	1	0	0	0
B30	24	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	1
B31	62	1	0	0	0	0	0	0	1	1	1	0	1	0	0	1	0	0	0	0	1
B32	23	2	0	0	0	0	0	0	1	1	0	1	3	0	1	1	0	0	0	0	1
B33	17	1	0	0	0	0	0	0	1	1	1	0	1	0	1	0	0	1	0	0	0
B34	63	1	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	1	0	0	1
B35	43	2	0	0	0	0	0	0	0	1	1	0	1	1	0	0	1	1	0	0	0
B36	23	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
B37	24	1	2	2	0	0	0	0	1	1	0	0	3	1	0	1	0	0	1	0	1
B38	30	2	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0
B39	23	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1
B40	24	2	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1	1	0	0	1
B41	47	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0
B42	20	1	0	0	0	0	0	0	1	1	0	0	0	3	0	0	1	1	0	0	0
B43	53	2	0	2	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0
B44	39	2	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	1	0	0	0
B45	27	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0
B46	50	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0
B47	35	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0
B48	29	1	0	2	0	0	0	0	1	1	1	0	0	3	0	0	0	1	0	0	0
B49	25	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0
B50	50	2	0	0	0	0	0	0	1	1	1	0	0	3	0	0	0	1	0	0	1

ID	SOEC left	IFC right	IFC left	UP right	UP left	APD right	APD left	TD right	TD left	Area right	Area left	AEA RIGHT	AEA left	Fovea	Kero right	Kero left	Top right	Top left
A01	0	0	0	1	1	5.43	5.93	6.8	3.58	28.96	16.67	3	2	3	1	1	1	1
A02	1	1	0	2	2	9.17	6.51	7.03	4.54	50.6	25.12	3	3	1	2	2	1	1
A03	0	0	0	2	2	4.43	6.16	2.87	4.42	9.98	21.37	2	2	2	2	2	1	1
A04	1	0	0	1	1	7.35	8.29	7.26	7.48	41.89	48.68	3	3	1	2	2	1	1
A05	0	0	0	5	5	3.37	4.42	3.5	3.21	10.02	11.14	1	1	3	1	1	1	1
A06	0	0	0	1	1	2.65	6.91	2.69	2.88	5.6	5.62	3	1	3	1	1	1	2
A07	0	1	0	1	1	5.4	3.51	8.87	10.25	37.6	20.2	3	2	2	2	2	1	1
A08	1	0	0	5	5	2.6	2	9.02	9.27	18.4	14.55	2	3	1	1	1	1	1
A09	1	1	0	1	6	4.33	5.33	7.56	9.18	25.67	38.4	2	3	2	2	2	1	1
A10	0	0	0	1	1	4.77	4.77	3.56	6.61	13.33	24.75	2	2	3	2	2	1	1
A11	0	0	0	5	1	6.28	14.83	10.54	8.89	51.96	103.49	3	3	2	2	2	1	2
A12	1	0	0	1	1	6.73	8.06	9.19	5.82	48.55	36.82	1	2	3	2	2	1	1
A13	0	1	1	1	1	6.06	4.04	8.61	7.05	40.96	22.35	1	1	2	2	2	1	1
A14	0	0	0	2	2	7.98	7.79	6.07	8.37	38.02	51.18	3	2	3	2	2	2	2
A15	0	0	0	1	1	7.27	7.26	6.95	5.15	39.66	29.35	2	2	2	2	2	1	1
A16	1	0	0	2	1	9.93	9.16	8.97	11.45	69.92	82.33	3	3	1	1	1	2	2
A17	1	0	0	1	0	9.2	8.85	5.72	6.2	41.3	43.07	3	3	3	2	2	2	1
A18	0	0	0	1	0	4.52	5.3	3.62	3.97	12.97	16.51	1	1	1	2	2	2	2
A19	0	0	0	6	1	10.31	3.98	6.77	7.04	54.79	22	3	1	3	2	2	2	2
A20	0	0	0	1	1	6.08	7.75	3.49	4.84	16.66	29.45	1	1	1	2	2	1	1
A21	0	0	0	0	0	7.49	5.07	6.98	8.65	41.04	34.42	2	2	2	2	2	1	2
A22	0	0	0	1	6	4.36	4.98	5.81	7.63	19.89	29.83	1	2	2	2	2	2	2
A23	1	1	1	2	2	6.4	7.45	8.97	9.65	45.06	56.44	3	3	2	1	1	2	2
A24	1	0	0	2	2	9.26	8.43	4.25	9.05	30.89	59.89	3	3	1	2	2	1	1
A25	0	0	0	6	0	6.26	6.78	6.47	7.22	31.79	38.43	3	3	1	2	2	1	2
A26	1	0	0	5	5	7.54	7.33	6.05	5.37	35.81	31.74	3	3	1	2	2	1	1
A27	0	0	0	0	0	5.03	6.01	10.74	7.62	42.41	35.95	3	3	3	2	2	1	1
A28	0	1	0	1	2	2.9	7.15	4.97	6.68	11.31	37.49	1	1	2	2	2	2	2
A29	0	0	1	2	1	9.38	8.1	4.47	6.04	32.91	38.4	2	2	2	2	2	2	2
A30	0	0	0	0	0	6.2	9.58	6.2	6.98	31.15	52.49	2	2	2	2	2	1	1
A31	0	0	1	5	6	6.19	4.79	8.12	4.44	39.46	16.7	2	3	3	2	2	1	1
A32	0	0	1	0	0	12.36	3.93	5.2	5.63	50.45	17.37	2	3	3	2	2	1	1
A33	0	0	0	0	0	8.52	9.42	8.38	9.4	56.04	69.51	3	3	2	2	2	2	1
A34	0	0	0	0	1	6.89	6.5	6.12	5.83	33.1	29.74	2	2	1	1	1	1	1

ID	SOEC left	IFC right	IFC left	UP right	UP left	APD right	APD left	TD right	TD left	Area right	Area left	AEA RIGHT	AEA left	Fovea	Kero right	Kero left	Top right	Top left
A35	0	1	1	5	1	5.19	7.02	3.14	6.07	12.79	33.45	1	1	3	2	2	2	2
A36	1	0	0	2	2	3.56	5.5	2.48	3.16	6.93	13.64	2	3	2	2	2	1	2
A37	0	0	0	1	1	8.32	6.4	5.6	5.6	36.57	28.13	2	2	1	1	1	1	1
A38	0	0	0	1	0	5.14	5.69	5.39	7.4	21.75	33.05	1	1	3	1	1	1	1
A39	0	1	0	1	1	5.45	7.31	5.8	13.5	24.81	77.47	1	1	1	1	1	1	1
A40	1	0	1	1	1	8.53	13.33	4.68	7.19	31.38	75.24	3	3	3	2	2	1	1
A41	0	0	0	1	1	8.2	9.49	6.82	5.71	43.9	42.54	3	3	2	2	2	1	1
A42	1	0	0	5	5	6.82	4.68	10.05	9.86	53.8	36.22	3	2	1	2	2	2	1
A43	0	0	0	2	2	5.9	8.61	8.45	7.2	39.14	48.66	3	3	2	2	2	2	2
A44	0	0	0	2	2	7.71	8.13	5.73	6.2	34.68	39.57	3	3	2	2	2	2	1
A45	1	1	0	6	5	7.09	8.13	8.04	9.21	44.75	58.78	2	2	3	1	1	2	2
A46	1	0	0	2	2	8.67	10.14	6.93	9.35	47.17	74.43	3	3	1	2	2	2	2
A47	0	0	0	1	1	7.29	9.22	6.03	7.03	34.5	50.88	3	3	2	2	2	1	1
A48	0	0	1	2	4	6.98	6.98	5.73	6.02	31.4	32.99	3	3	3	2	2	1	1
A49	0	0	1	2	5	6.21	2.89	4.3	6.08	20.96	13.79	3	3	2	2	2	1	1
A50	1	0	1	2	2	7.49	9.28	9.03	11.55	53.09	84.14	3	3	2	2	2	1	1
B01	0	0	0	1	1	6.1	7.8	6.21	3.04	29.73	18.61	3	3	3	2	2	1	1
B02	0	0	1	3	3	8.6	7.8	4.14	3.4	27.95	20.82	3	3	3	2	2	1	1
B03	1	0	0	3	3	5.6	5.4	8.5	7.15	37.36	30.31	3	3	3	2	2	2	2
B04	0	0	0	3	3	5.2	5.8	7.93	5.4	32.37	24.59	3	3	2	1	1	1	1
B05	0	0	0	5	5	3.2	3.4	3.99	3.3	10.02	8.8	1	1	2	1	1	2	2
B06	1	0	0	2	1	3.4	3.4	6.18	6.09	16.49	16.25	3	3	2	2	2	1	1
B07	0	0	0	3	3	4.9	6.9	9.64	8.21	37.08	44.47	2	3	2	2	2	2	2
B08	0	0	0	1	1	4.2	2.8	6.31	5.26	20.8	11.56	3	1	3	2	2	2	2
B09	0	0	0	3	3	4.3	3.7	6.84	9.25	23.08	26.87	3	3	2	1	1	2	2
B10	0	0	0	3	2	5	2	5.86	8.24	23	12.94	1	2	2	2	2	2	2
B11	0	0	0	2	2	3.9	2.9	2	6.46	6.12	14.71	3	1	2	2	2	1	2
B12	1	0	0	3	3	14	12.9	7.17	10.85	78.8	109.87	3	3	2	2	2	1	1
B13	0	0	0	1	1	4.3	5.8	2.08	3.95	7.02	17.98	2	2	2	1	1	1	1
B14	0	1	0	3	3	5.5	8.7	8.38	9.33	36.18	63.72	3	3	2	2	2	1	1
B15	1	0	0	3	3	5.4	4.8	6.6	6.6	27.98	24.87	3	3	3	2	2	1	1
B16	1	0	0	3	3	4.9	4.7	5.1	5.56	19.61	20.51	3	3	2	2	2	2	2
B17	0	0	0	1	2	3.2	5.7	4.6	3.14	11.56	14.05	2	2	2	2	2	2	2
B18	1	0	1	3	3	2.3	3.3	3.37	3.17	6.08	8.21	3	3	2	2	2	2	2
B19	1	0	0	1	1	5.05	5.82	3.48	2.61	13.8	11.92	2	2	1	2	2	2	2

ID	SOEC left	IFC right	IFC left	UP right	UP left	APD right	APD left	TD right	TD left	Area right	Area left	AEA RIGHT	AEA left	Fovea	Kero right	Kero left	Top right	Top left
B20	1	0	0	3	3	10	6.5	6.3	7.9	49.46	40.31	3	3	2	2	2	2	1
B21	0	0	0	2	2	1.6	3.8	8.3	7.1	10.42	21.18	2	2	2	2	2	2	2
B22	0	0	0	3	3	6.5	7.7	6.2	6.2	31.64	37.48	2	3	2	1	1	2	2
B23	1	0	0	1	3	5.9	4.6	2.67	6.09	12.37	6.09	3	3	2	1	1	2	2
B24	0	0	0	5	3	2.3	2	6.6	8.2	11.92	12.87	2	2	2	2	2	2	2
B25	1	0	0	1	3	2.9	2.1	6	6	13.66	9.9	3	3	2	2	2	1	1
B26	1	0	0	3	3	7.6	7.2	7.5	6.6	44.75	37.3	2	3	2	2	2	1	1
B27	1	0	0	2	2	5.9	7	9	6.6	41.68	36.27	3	3	2	1	2	2	2
B28	1	0	0	3	3	5.1	6.3	3.5	7	14.01	34.62	3	3	2	2	2	2	1
B29	0	0	0	2	2	5.66	4.22	4.11	2.15	18.26	7.12	3	2	2	2	2	1	1
B30	1	1	0	3	2	6.03	6.8	6.51	6.52	30.81	34.8	3	3	3	2	2	1	1
B31	1	1	0	2	2	9.62	8.78	10.51	7.36	79.36	50.73	3	3	2	3	2	1	2
B32	1	0	0	1	2	4.37	8.17	2.44	3.57	8.37	22.9	3	3	2	2	2	2	2
B33	0	0	0	2	2	5.33	4.89	6.16	3.74	25.77	14.36	1	1	1	2	2	1	1
B34	0	0	0	6	2	4.4	12.12	7.94	1.78	27.42	16.94	3	2	2	2	2	1	1
B35	0	1	0	1	1	6.57	6.49	6.51	5.93	33.58	30.21	2	2	2	2	2	1	1
B36	0	0	0	1	1	4.81	4.98	8.04	7.82	30.56	30.57	1	2	1	1	1	1	1
B37	0	1	0	2	2	3.9	8.33	9.76	6.73	29.88	44.43	3	3	2	2	2	1	1
B38	0	0	0	2	1	3.69	2.1	6.48	6.11	18.77	10.07	3	3	1	2	2	1	1
B39	0	0	0	2	5	4.66	3.21	3.77	8.03	13.8	20.39	3	3	2	2	2	1	1
B40	0	1	0	1	3	8.43	7.97	8.54	3.47	56.51	21.7	2	3	2	1	1	1	1
B41	0	1	0	3	2	8.88	8.41	8.81	8.6	61.41	56.78	1	2	2	3	2	1	1
B42	0	1	0	5	3	7.93	3.59	2.6	7.09	16.18	19.98	2	2	2	2	2	1	2
B43	1	0	0	3	5	6.55	7.52	8.03	8.25	41.29	48.7	1	2	2	2	2	1	1
B44	0	0	0	1	1	5.2	6.48	4.09	3.3	16.7	16.79	2	2	1	2	2	2	1
B45	0	0	0	6	6	6.91	7.63	5.89	7.63	31.94	31.62	2	3	2	2	2	1	1
B46	0	0	0	6	3	5.67	7.25	6.33	5.03	28.17	28.63	2	2	1	2	2	1	1
B47	0	0	0	2	2	5.97	3.99	8.07	7.38	37.82	23.12	1	1	2	2	2	1	1
B48	1	1	1	1	3	5.15	1.65	4.56	5.64	18.43	7.3	2	3	2	2	2	1	1
B49	0	0	0	1	5	11.3	11.18	4.56	5.64	40.45	49.5	3	3	2	2	2	1	1
B50	0	0	0	3	2	9.65	3.31	5.67	5.89	42.95	15.3	3	3	2	2	2	1	1